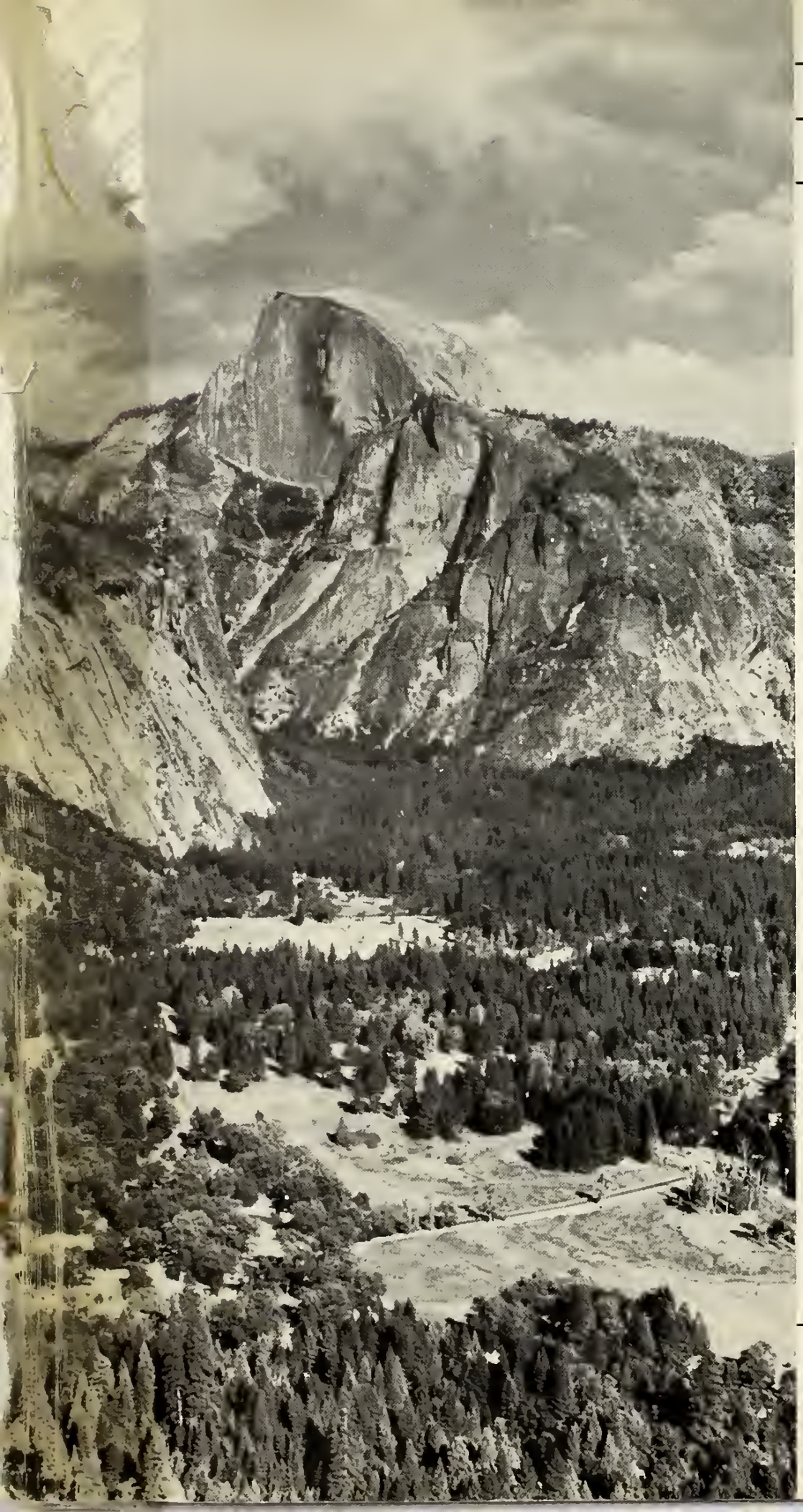

Division of Agricultural Scie
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The Influence of Modern Man on the Vegetation of Yosemite Valley

ROBERT P. GIBBENS · HAROLD F. HEADY

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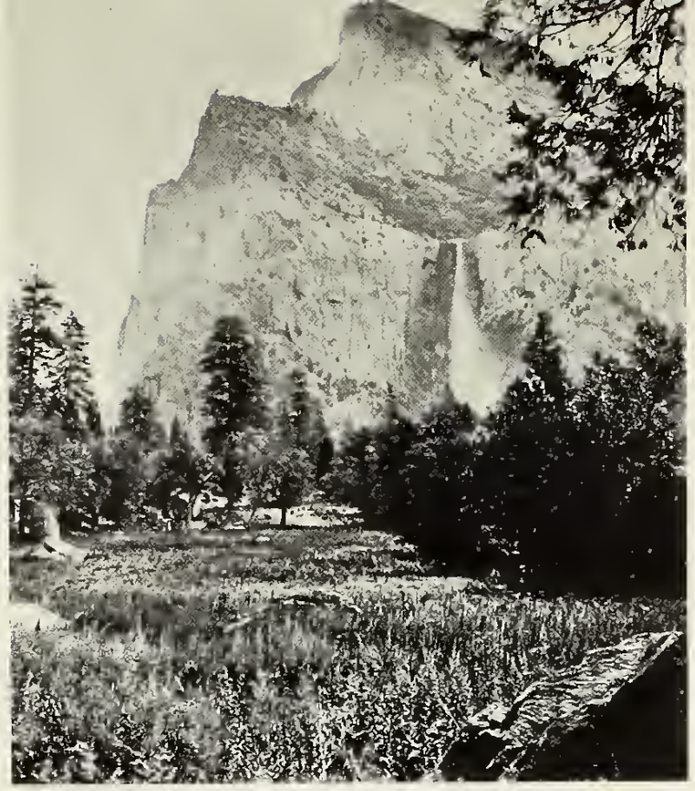

ROBERT P. GIBBENS and HAROLD F. HEADY

The Influence of Modern Man on the Vegetation of Yosemite Valley

This publication compares the present vegetation of Yosemite Valley with that existing in 1851 as depicted by early writings and photographs, and discusses the changes—both man-made and natural—which have occurred since then.

UNIVERSITY OF CALIFORNIA · DIVISION OF AGRICULTURAL SCIENCES

Contents

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JULY, 1964

Introduction

RECREATION in wildland areas is a major land use which is rapidly gaining in extent and intensity. Because of this, recreationists may possibly destroy their favorite wildland areas through sheer numbers and overuse. To preserve the recreational values of such areas their natural conditions must be understood and the changes caused by recreational use determined. Because its spectacular scenery has attracted so many visitors, Yosemite Valley has a well-documented history as a recreation area, and thus offers a unique opportunity for study of changes caused by recreationists.

Yosemite Valley is young geologically, although its age is great when compared with its short historical period. Man is a newcomer to the Valley, but in his short tenure he has exerted a great influence on its vegetation. Aboriginal man manipulated the Valley's vegetation to supply his basic needs, but modern man has been more of an exploiter. Fortunately, exploitation of the Valley was tempered by the early realization that its scenic values were unique and should be preserved.

Since 1864, when Yosemite Valley was set aside as a public trust, two objectives have guided its management: perpetuating natural conditions for continued enjoyment and, secondly, encouraging public use. But attempts to attain both objectives inevitably result in conflict as more and more disturbance of natural conditions is caused by the ever-increasing influx of visitors. How much disturbance of natural conditions has occurred? How much can be allowed? Before these questions can be answered, an understanding of natural and man-caused vegetational changes in the valley is needed.

Non-biological forces—such as rainfall, wind, fire, and climate—fluctuate, and thus influence biological communities. Additionally, the development of a biological community often so alters its own conditions that some other community replaces it. This constant interplay of physical and biological forces unhindered by man also results in continual, though often unrecognized, changes of the natural state. Man can, and often does, cause additional change, as did the Indians inhabiting Yosemite Valley before 1851. Their influence on the vegetation is recognized but not examined in detail in these pages, as major emphasis is given to man's influence on the natural scene since 1851.

The objectives of this study, which was conducted in 1961, were (1) to define natural conditions existing in the Valley in 1851, and (2) to determine the role of historical events in changes which have led to the Valley's present patterns of forest and meadow. With such information, more accurate predictions of landscape-management results are possible, and as a result the biologist is better prepared to furnish his share of the information needed to strike a balance between the natural scene and the vegetational changes caused by recreational use of the Valley.

Events affecting the vegetation

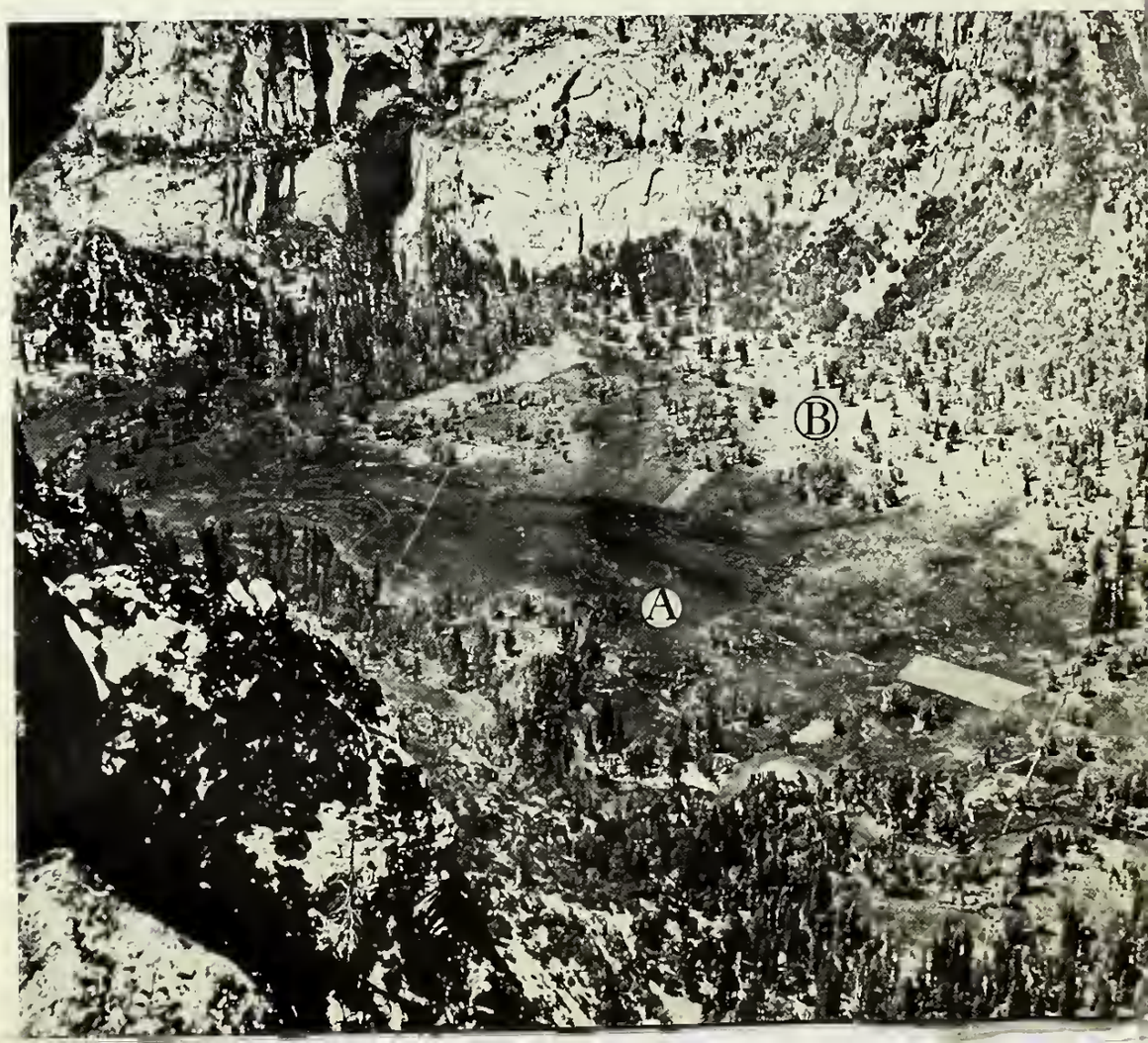
CHRONOLOGIES of historical events in Yosemite Valley have been prepared by Russell (1959) and by Paden and Schlichtmann (1955). Accounts of the Valley's early history were also recorded by Hutchings (1886) and Bunnell (1911). The year 1851 marks the first recorded entry of modern man into the Valley. Prior to this the Valley had been part of the territory occupied by the Awanichi, a small tribe of Miwok Indians. This tribe left the Valley in the late 1700's or early 1800's, but a Miwok group re-entered the Valley at least one generation before 1851. Considerable evidence indicates that the Indians used fire and hand-eradication methods to control brush and tree growth in the Valley (Ernst, 1943; Reynolds, 1959).

By 1854 the tribe was drastically reduced in numbers and their culture, as a major influence on the vegetation, had largely ended. This disruption of the Indian culture was, indirectly, the first influence of white man on the vegetation. If we credit the Indians with slowing down the ecological succession of plants in the Valley, the period of change thus began in about 1854. Thomas Ayres made the first published sketches of the Valley in 1855 and these, plus written descriptions, brought publicity that greatly accelerated the Valley's occupation.

Events now happened swiftly. The first trail to the Valley was completed in 1856. The first permanent structure, the "Lower Hotel," was erected in 1856 near the base of Sentinel Rock, and the "Upper Hotel" was built near the present Sentinel Bridge in 1858; these sites were focal points of activity for many years. The first settler, James C. Lamon, located a preemption claim in the upper end of the Valley in 1859, built a log cabin, planted an orchard, and cultivated a garden. With the arrival of J. M. Hutchings and his family in 1864, year-round occupation was firmly established. Hutchings also planted an orchard and cultivated a garden; hay was harvested, fields were plowed to provide grain, and buildings were constructed. Thus, some of the meadowlands and woodlands began to be affected.

The year 1864 saw Yosemite Valley and the Mariposa Big Tree Grove granted to the state of California as a public trust. A

Figure 1A. Yosemite Valley from Glacier Point, 1866, showing the Hutchings' home, corral, and several split-rail fences. Photograph by C. E. Watkins.



survey to establish the boundaries of the grant, which extended back from the cliffs an average distance of one mile, was made in the same year. Commissioners to manage the grant were organized in 1866, when legal acceptance of the grant by the State was completed.

Between 1870 and 1880 tourist facilities rapidly expanded and trails were constructed to Glacier Point, Nevada Falls, and other areas. In 1874 the Coulterville and Big Oak Flat stage roads made entry to the Valley. During the 23 years when access was by horse trail only, over 12,000 persons visited the Valley and by 1878 the influx of visitors necessitated the establishment of the first public campground. The Commissioners did not attain full control of the Valley until 1875 when claims of the early settlers were finally extinguished. However, leases were still granted and few land-use restrictions were placed on lessees.

The following statements, from the 1880 Commissioners' Report, indicate that conditions in the Valley were causing concern:

1. Most of the available land is under lease for pasture and garden purposes.

2. The enclosed fields are being invaded by willows, wild roses, and other growth, to the damage of their value and of the beauty of the Valley.

3. The upper portion of the Valley, which has been set apart for the convenience of campers, is largely overgrown with willows and young pines. The views are obstructed, the pasturage destroyed, and the appearance injured.

4. There is no practicable and unobstructed carriage road around the Valley, near the base of the cliffs. At present all who attempt to make the circuit of the floor of the Valley, must pass through gates and fields, lose some of the finest views, and be subjected to annoyance and loss of time.

Figure 1B. View from Glacier Point, 1943. National Park Service photograph.

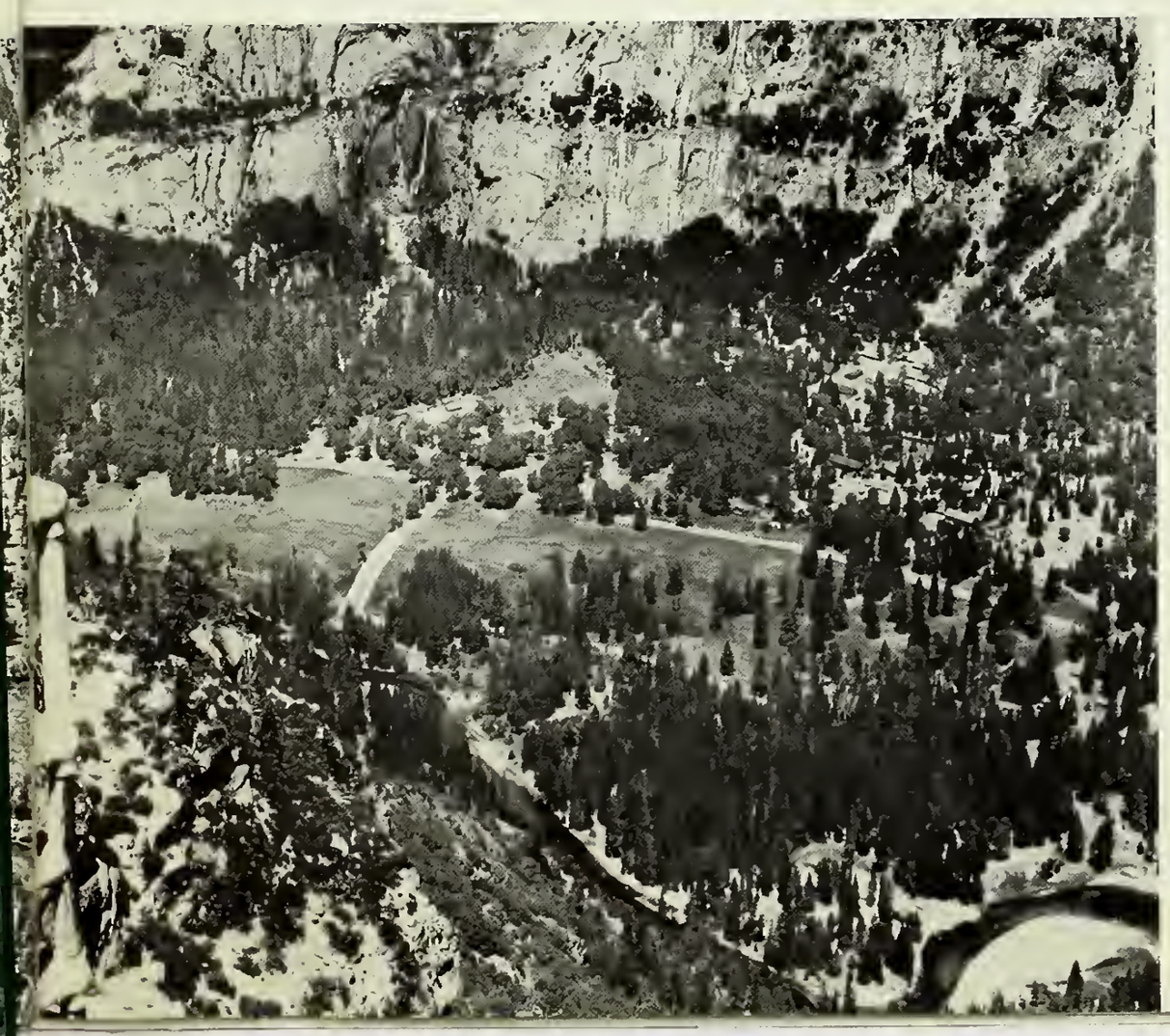


Figure 1C. Yosemite Valley from Glacier Point, 1961. Photograph by R. P. Gibbens.

Encroachment of trees into the meadows now aroused increasing comment. The Commissioners' Report for 1887–1888 mentions clearing of undergrowth and pruning of trees in front of the Stoneman House (a hotel constructed by the State) and other areas in the upper end of the Valley. The same report contains one of the few accounts of fires in the Valley since 1851:

> Several times during the period of my labors on your behalf, it required suddenly almost the entire force of twenty or thirty men to divert the all consuming course of forest fires on the floor of the valley. Since the annual practice of the Indians in burning off the dried grasses and leaves has been discontinued, and even forbidden by law, the accumulation of vegetable matter beneath the trees has been practically undisturbed, until a growth of young pines has sprung up all over the valley, and destroyed much fine meadow land. A campfire carelessly left, or a match thrown among the leaves, has caused several fires within the past two or three years that could not be extinguished. They burned until the walls, the roadway, and streams defined and determined their course.

Such fires would have an effect on existing and subsequent vegetation.

In 1881 W. H. Hall, then the State Engineer, visited the Valley and recommended extension of the grant to control the entire watershed of the Valley, regulation of grazing, clearing of brush and trees, and "perhaps" the plowing and reseeding of meadow lands. He also suggested clearing and irrigating non-meadow lands to increase the forage supply (Hall, 1882). These recommendations may have influenced land use. "Farming" activities had reached such proportions by the late 1880's that public opposition to the management of the Valley was aroused. Complaints centered around the presence of fences throughout the Valley, the use of meadows for pasturage and hay by operators who charged the public high prices, and the cutting of trees. This led to an investigation by the State Senate in 1889; in 1890 a new board of commissioners was appointed and a few corrective measures instigated.

Manipulation of vegetation to alleviate fire hazard was carried out during the 1890's, but not without criticism. The report of a

Figure 2A. Lower Yosemite Valley from Union Point, 1866. The "arboriferous belt" described by Whitney (1868) is clearly evident at the base of talus slopes on valley sides. Photograph by C. E. Watkins.

special land investigator detailed to examine the Valley is included in the Report of the Secretary of Interior for 1892:

> A good deal of underbrushing has been done near the Stoneman House in Yosemite Valley and around the stables of the Transportation Company by direction of the State commission, under the supervision of Galen Clark, the guardian. . . . He [Galen Clark] took me around to the places where the clearing had been done for the purpose of lessening the danger of fires, and which, it is true, at times partook of the nature of a mutilation of natural beauty.

California's administration of the Valley ended with cession of

Figure 2B. Lower Yosemite Valley from Union Point, 1943. The original view was blocked by trees which had grown in the foreground. This vantage point is a short distance to the left of the one in 1866. The old Sewer Farm, a man-made clearing, appears at the top of the foreground tree. National Park Service photograph.

Figure 2C. Lower Yosemite Valley from Union Point, 1961. The rock slide appearing at the base of Cathedral Spires (upper left) in 1866 has been nearly obliterated by vegetation. Photograph by R. P. Gibbens.

the Valley and the Mariposa Grove to the Federal Government in 1905. The Commissioners were replaced by the U. S. Army, which administered Yosemite National Park for the Department of Interior. Reports of the military commanders indicate that grazing, mowing, and cultivation continued. There was considerable comment on the necessity of clearing thickets but apparently no action was taken until 1911, when some undergrowth was removed.

Automobiles were admitted into the park in 1913 and the number of visitors increased sharply; by 1915, motor stages had replaced horse-drawn stages in the Valley. Although grazing and hay growing declined with the advent of cars, most of the meadows were grazed until 1924 when the last dairy herd and most of the fences were removed. These early fences delimited grazed areas and served as boundaries for clearing operations, and their removal opened the meadows to tourists who picnicked, camped, and drove over them. Ditches were constructed to halt this use in 1929, but the ditches may have had more far-reaching consequences by affecting drainage.

Army administration of the Valley ended with the formation of the National Park Service in 1916. By 1920 policies of this agency were well established, and one idea emphasized was the "vista-clearing" concept (Punchard, 1919). Vista-clearing and general

improvement activities reached unprecedented levels when abundant labor was made available during the 1930's: ditches were constructed, campgrounds delimited, screening trees planted, dead trees removed, thickets thinned, insect-infested trees cut and burned, young trees cut from meadows, meadows drained for mosquito control, river and creek channels cleared, banks sloped and covered to halt erosion, low areas filled, ground squirrels eradicated, and deer trapped and removed. According to the Superintendent's Monthly Reports for the 1930's, there were few areas in the Valley which did not receive a face-lifting of some sort. These landscaping activities ended with the start of World War II.

After the war, activities affecting vegetation were largely confined to maintenance-type work: thistle control in the meadows, removal of dead and dangerous trees, limited vista-clearing, relocation of the Old Village and other structures. In post-war years, the dominant factor affecting vegetation has been the increase in the number of visitors, now (1963) numbering over 1,200,000 persons yearly.

Vegetation at the time of discovery

UNFORTUNATELY, we have only meager descriptions of the vegetation of the Valley at the time of its discovery by white man. Plants and vegetation were weak rivals for attention compared with cliffs

Figure 3A. Lower end of Yosemite Valley in 1866 from Old Inspiration Point. The large open area in the lower left part of picture is Bridalveil Meadow. Note the open character of the forest on north (left) side of river. Photograph by C. E. Watkins.

Figure 3B. View from Old Inspiration Point, 1961. The old Big Oak Flat road can be seen on the talus slope north of the river. Photograph by R. P. Gibbens.

and waterfalls when early descriptions were written, and this is true today. Even such naturalists as John Muir, who spent much time in Yosemite and wrote of it extensively, recorded little specific information on its flora; statements like "Verdant banks of new leaves, and groves of half-open ferns, and thick settlements of confident flowers . . ." (Muir, 1915) are of little scientific value. Fortunately, a few sources containing other observations were found. A brief comment on vegetation by a member of the Mariposa Battalion which entered the Valley in 1851 was included in the Commissioners' report for 1889–1890:

> The valley at the time of discovery presented the appearance of a well kept park. . . . There was then little undergrowth in the park-like valley, and a half day's work in lopping off branches along the course enabled us to speed our horses uninterrupted through the groves.

Galen Clark, in a letter to the Commissioners dated August 30, 1894, said, in part:

> My first visit to Yosemite was in the summer of 1855. At that time there was no undergrowth of young trees to obstruct clear open views in any part of the valley from one side of the Merced River across to the base of the opposite wall. The area of clear open meadow ground, with abundance of luxuriant native grasses and flowering plants, was at least four times as large as at the present time.

Sketches by Thomas Ayres, the artist who visited the Valley with J. M. Hutchings in 1855, also suggest that trees were widely spaced on the Valley floor.

In 1866 the State Geographical Survey party under direction of J. D. Whitney made a detailed geographical and geological survey of the Yosemite Valley region. This survey, published in 1868 as *The Yosemite Book,* contains the first detailed descriptions of vegetation. It seems unlikely that extensive changes had occurred during the 15 years since 1851. The few Indians occasionally inhabiting the Valley continued the burning which was credited with maintaining the park-like appearance of the Valley. Baxley (1865) described his arrival at the Valley in the fall of 1861 as follows:

> A fire-glow in the distance, and then the wavy line of burning grass, gave notice that the Indians were in the valley clearing the ground, the more readily to obtain their winter supply of acorns and wild sweet potatoe [sic] root—'huckhau.'

Whitney (1868) included a lengthy description of the vegetation in 1866 (currently-used names are in brackets):

> Along the banks of the river and over the adjacent rather swampy meadows, we find a somewhat varied vegetation, according to the locality, the narrow portions of the Valley differing considerably from the broader ones. In the former, near the falls, there is a dense growth of alder (*Alnus viridis*), [*A. rhombifolia*] . . . associated with this are small trees of *Rhamnus Menziesii,* [??]. . . . A few willows [*Salix* spp.], the Douglas spruce (*Abies Douglasii*), [Douglas-fir, *Pseudotsuga menziesii*] and, in the upper part of the Valley, an occasional sugar pine [*Pinus lambertiana*], are also found in this position. Where the Valley widens out, and the river banks become lower, so that sloughs and swamps are formed, the Balm of Gilead popular (*Populus balsamifera*) [black cottonwood, *P. trichocarpa*] comes in; this is a common tree in the Valley, . . . with this occur large willows and abundance of the Douglas spruce, and also the *Azalea occidentalis,* . . . . The meadows are swampy, with a deep peaty soil; their vegetation consists chiefly of carices or sedges and a few coarse grasses . . . .
>
> The sandy region of the Valley proper forms a connecting strip along the edge of the rocky talus, on both sides of the river. . . . This is peculiarly the arboriferous belt of the Valley, and various portions of its area exhibit different characters of vegetation to correspond with the differences of soil. On the drier and looser portions, the pitch (or yellow) pine (*P. ponderosa*) and the bastard cedar [incense-cedar] (*Libocedrus decurrens*) are the most abundant and characteristic trees; both these species occur of considerable size and of fine proportions, the pines being usually from 125 to 150 feet high. Below the Bridal Veil Fall, near the debris, the fir (*Picea grandis*) [white fir, *Abies concolor*], a noble tree, comes in; near the swampy land, the black oak (*Q. Sonomensis*) [*Quercus kelloggii*] is

> abundant. The sandy regions also bears a great number and variety of shrubs and undergrowth; . . . .
>
> The most characteristic tree of the debris piles is, perhaps, the mountain live-oak [canyon oak] (*Q. chrysolepis*, Liebm.)

The spectacular scenery attracted early photographers, and their photographs provide the best means of determining vegetational changes. The first pictures were taken in 1859 by C. L. Weed, who took additional photographs in 1863. Examination of some of these show few changes between the above dates and 1866, when C. E. Watkins took an extensive series. The Watkins photographs (figs. 1A, 2A, and 3A) depict original conditions on the Valley floor.

Although white man had altered conditions to some extent by 1866 it seems reasonable that the vegetation was not greatly different from that of 1851. Whitney's description fits the conditions shown by the photographs—for example, the "arboriferous belt" is plainly visible in figures 1A and 2A.

Whitney (1868) also gives the extent of vegetational types. "There are, altogether 1,141 acres of land in the Valley proper, of which 745 are meadow, and the remainder, a sandy soil, a little more elevated, partly covered with a sparse growth of forest trees and partly with pertinacious ferns." The acreage figures were evidently based on a stylized plat prepared by a member of the survey party (fig. 4). Whitney evidently restricted his definition of meadows and "land in the Valley proper" to low-lying areas which were periodically flooded. Based on planimeter readings from the 1961 U. S. Geological Survey map of Yosemite Valley there are, from Pohono Bridge to the eastern end of the Valley, over 2,200 acres enclosed by the 4,000 foot contour line which roughly coincides with the base of the talus slopes. Vegetation in 1866 thus seems to have consisted of extensive wet meadows bordering the river and of open forests along the sides of the Valley.

In 1851 the tree population in the Valley was composed of two distinct age groups. One group consisted of old-growth stands, primarily black oak and scattered individuals of ponderosa pine, incense-cedar, white fir, and Douglas-fir; counts of growth rings indicate the age of this group to be largely in excess of 250 years. Reynolds (1959), besides noting the old-growth stands, observed a "stand of intermediate age" consisting of ponderosa pine and incense-cedar. On the basis of growth-ring counts, he placed the age of this group of trees at about 150 years, with the date of origin being 1800 plus or minus 10 years. According to Bunnell (1911), the Indians fled the Valley temporarily because of disease, and Reynolds speculates that the period when the Valley was empty might well have been about the year 1800; the trees were able to become established then because the Indians were not present to carry out their usual practice of burning.

The presence of the other group, intermediate-aged stands, is significant because it indicates that a trend toward the development of a forest cover existed before 1851. One wonders what preceded the old-growth stands? Plant succession only to a black oak stage in the 10,000 years since the filling of ancient Lake Yosemite seems highly unlikely. Plant succession probably did not pass through marsh, bog, and meadow stages because the lake was filled by delta formation which would allow colonization by trees on a well-drained substrata. The hypothesis that woody plants appeared at an early date is supported by Matthes (1930):

> It is probable, . . . , that like the [present] deltas at Merced Lake and Washburn Lake, the delta at the head of Lake Yosemite was largely covered with vegetation. Its more stable portions bore forest trees, and its shore was fringed with willows. That the climatic conditions permitted vegetation thus to establish itself can scarcely be doubted, for there are indications in various parts of the Sierra Nevada that even during glacial time extensive forests of pine and sequoia flourished on its lower slope and well up on the ridges between the canyons.

Evidence of former forests in Yosemite is found in old soil profiles in the talus slopes (Matthes, 1930). If forests developed enough

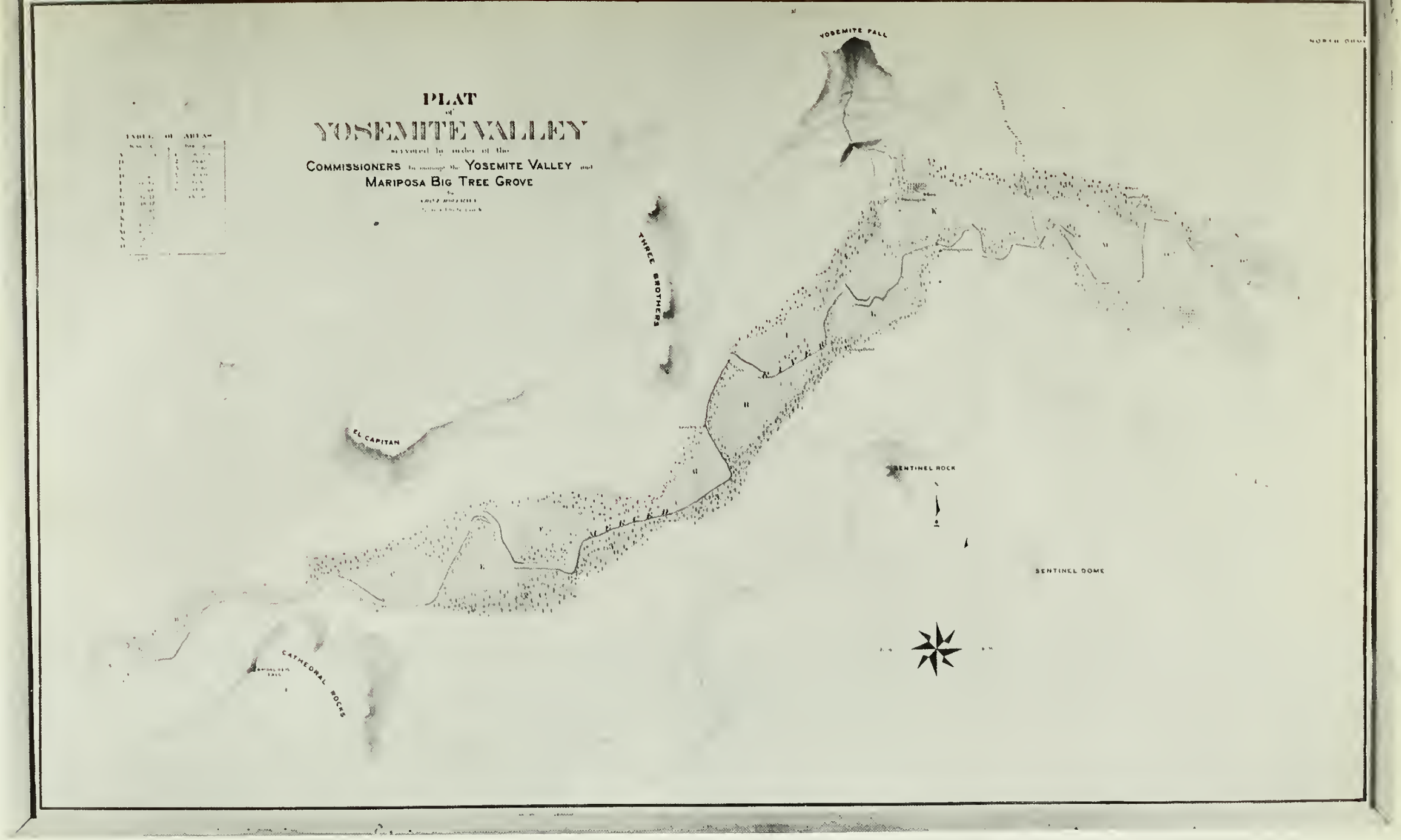


Figure 4. Plat of Yosemite Valley made by C. F. Hoffmann, a member of the State Geological Survey party, in 1866 or 1867. According to the legend there were 745.63 acres of meadowland and 395.93 acres of "fern and high lands" on the Valley floor.

on talus slopes to form soil profiles, it is likely that they also appeared on the Valley floor. Destruction of these ancient forests could be accounted for by rockslides or by fire. The probable establishment and destruction of past forests suggests that aboriginals arrived following, or took advantage of, such a destruction—and then arrested plant succession toward another forest cover at the stage best suited to their needs. As will be seen, the arrival of modern man brought other influences into play.

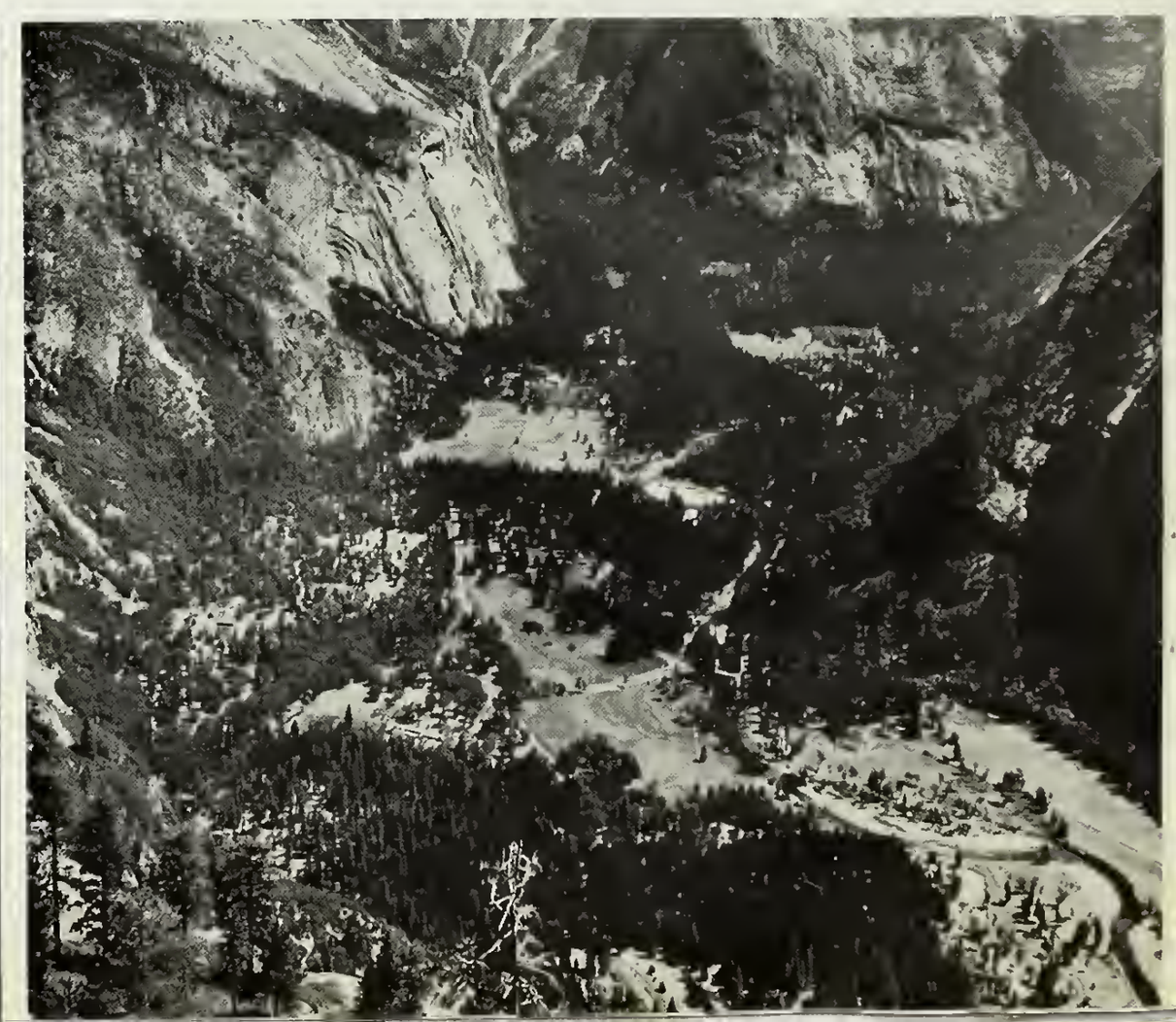
Tree increase

THE 1943 and 1961 photographs of areas covered by the 1866 photographs show a striking increase in the number of trees in the Valley, and most of this increase occurred before 1943 (see all photographs in figures 1, 2, and 3). The 1866 photographs do not show young trees, but trees younger than 4 or 5 years would probably not be visible; this is evidence that widespread establishment of trees took place after 1860.

Growth-ring counts were made of trees at various points throughout the Valley. The oldest trees on former open areas are about 90 years old (appendix fig. 1). Emil Ernst, a park forester for many years, made hundreds of ring counts on trees and found few older than 70 years (Ernst, 1943), and Reynolds (1959) placed the age of most trees in the Valley as post-1851. Thus, the oldest trees

Figure 5A. Yosemite Valley from Eagle Peak, probably in the late 1870's. The Cosmopolitan Walk (constructed in 1870—the straight white line in lower right), the Four Mile Trail to Glacier Point (1871), and the Sentinel Hotel (1876) are visible. Black oak predominates in upper end of Valley. Photographer unknown.

Figure 5B. View from Eagle Peak, 1943. National Park Service photograph.



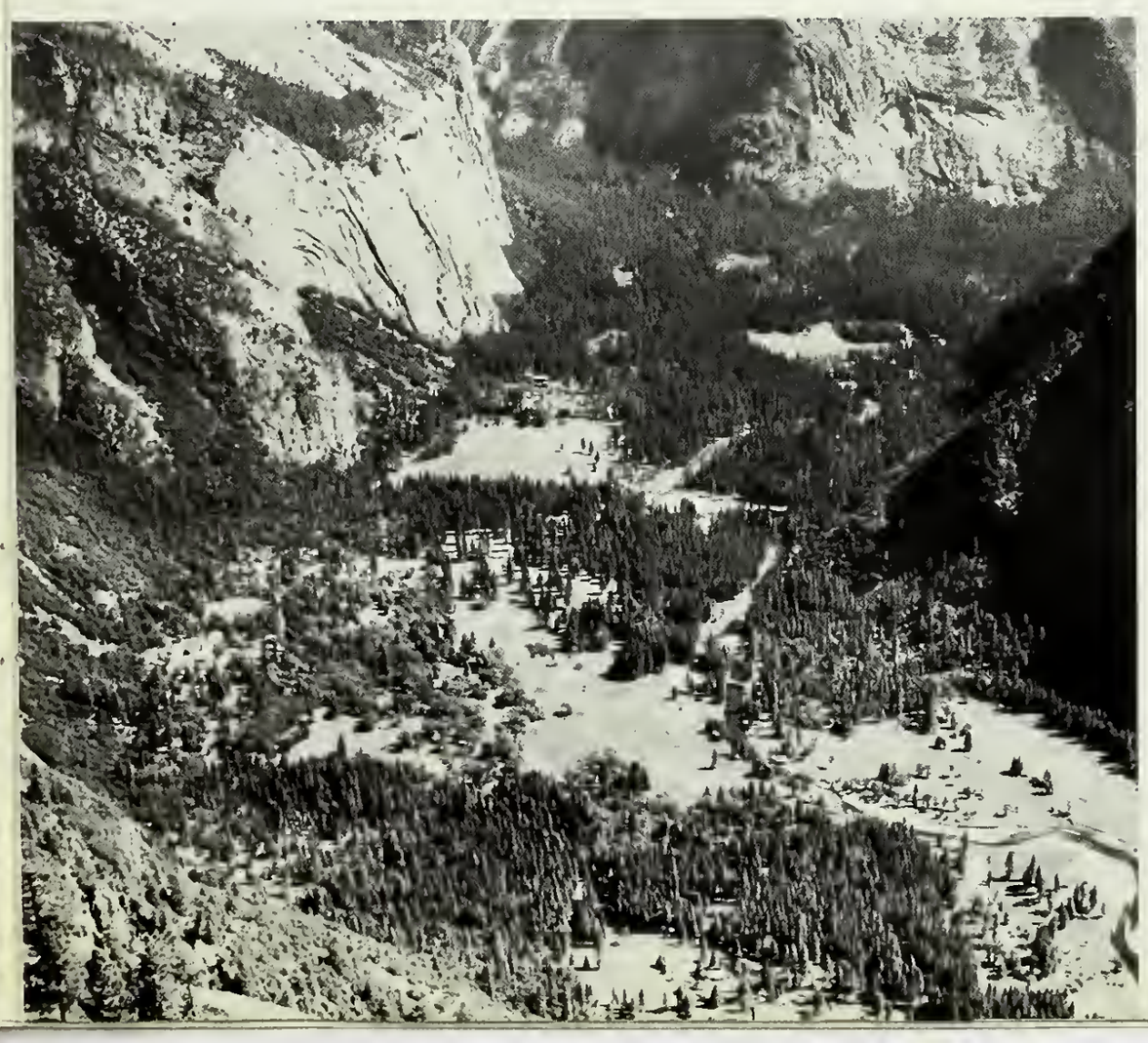
in the young forest which predominates in the Valley today must have appeared about 1870.

Contemporary reports, such as the following statement in the Commissioners' Report of 1882, confirm that the spread of trees took place between 1866 and 1880:

> In our brief report of 1880, we called attention to the rapidly increasing breadth of underbrush and second growth pines, and need not restate our convictions with respect to the importance of counterworking this spreading infestment. While the Indians held possession, the annual fires kept the whole floor of the valley free from underbrush, leaving only the majestic oaks and pines to adorn the most beautiful of parks.

Although 1880 is 10 years later than the date established by growth-ring counts, the time lag necessary for trees and shrubs to attain sufficient stature and density to attract attention is about what one would expect.

Figure 5C. View from Eagle Peak, 1961. Some of the trees formerly present on the Ahwahnee Meadow have been removed. Photograph by R. P. Gibbens.



Further evidence of the widespread invasion of trees and their rapid growth is furnished by photographs (figs. 5A, 6A) showing that establishment of trees occurred throughout the Valley on talus slopes, sandy delta remnants, dry meadows, and wet meadows. Although Ernst (1961) states that the area of wet meadow has remained about the same, photographic evidence indicates that very wet sites were invaded at an early date. Whitney (1868) refers to the meadows as "swampy." The dark color in area A on figure 1A suggests wet meadow. The early building of a board walk across this meadow is a further indication that inundation by overflow was common, and that swampy conditions prevailed during at least part of the year.

Another example of invasion of a wet habitat is Black Spring (see all photographs in figure 7). This area was an open spring-fed drainageway in 1866, and Hutchings (1882) described road-building activities across the area:

> From the Phono Bridge we followed up our work on the north-ern side of the Valley to Black Springs. This is a wet and swampy place, which required ditching on both sides for nearly two hundred feet, and three rock-covered culverts for drainage.

The road may have altered the drainage and created drier conditions but some of the trees now growing in the area became established before the road was built. Other examples of forest encroachment on what must have been wet sites are found throughout the Valley.

Dry habitats were also readily invaded by trees. In figure 1A, area B shows a bare, sandy site which is now covered by a stand of trees. The increase in number of trees along the base of the talus slopes is evident in figure 2. But increase in density is not confined to the Valley floor; canyon oak has increased in number and size on the talus slopes (see all photographs in figures 1, 2, and 3).

Ponderosa pine and incense-cedar were the primary but not the only woody plants which increased on the Valley floor. Young

Figure 6B. View from Columbia Point, 1943. National Park Service photograph.

Figure 6C. View from Columbia Point, 1961. Photograph by R. P. Gibbens.

stands of white fir are found in certain areas, and willows and wild roses (*Rosa* spp.) are listed as invaders of open fields in the Commissioners' Report for 1880. Galen Clark (1894) noted that young willows and cottonwoods were becoming so thick on the meadows that little clear ground was left. Today, only a few of these plants survive.

The rapid growth of conifers has greatly changed the appearance of extensive woodland areas formerly dominated by black oak (see all photographs in figure 8). Black oaks are still present, but they have been overtopped by conifers and are no longer dominant. Ponderosa pine and incense-cedar are now the most abundant trees and dominate most of the forested areas on the Valley floor (appendix tables 1 and 2). Small areas are dominated by white fir, Douglas-fir, black oak, black cottonwood, and alder. Canyon oak is dominant on most of the talus slopes.

In the forest stands outside the Valley's campgrounds the increase in tree density has been a continuing process, and there is often a continuous range of tree ages and sizes from seedlings to the pre-1851 trees (figs. 9, 10). Growth of the understory trees is slow, as can be seen by the ages of trees with a small diameter (appendix fig. 1). Recent tree establishment has not been confined to forest

Left, Figure 6A. View of upper end of Yosemite Valley from Columbia Point, 1899. Pre-1851 conifers are plainly visible above the stands of black oak and young trees. Photograph by H. G. Peabody.

Figure 7A. Right, top. The Black Spring area, 1866. Photograph by C. E. Watkins.

Figure 7B. Right, center. The Black Spring area, 1943. A small rock has rolled against the larger one since the 1866 photograph was taken. National Park Service photograph.

Figure 7C. Right, bottom. The Black Spring area, 1961. Tree in left foreground is about 73 years old; small incense-cedars in center are 65 to 70 years old. Flowering dogwood has become established since 1943. Photograph by H. F. Heady.

stands, however, as young trees are found on meadows and other open areas (figs. 11, 12).

The development of a dense tree canopy has created conditions favorable for the establishment of shade-loving plants within the forest. The high shade tolerance of incense-cedar accounts for its abundance as an understory in dense stands. Young trees and seedlings of two other shade-tolerant species, white fir and Douglas-fir, have appeared in the dense stands of ponderosa pine and incense-cedar. It is possible that white fir will in time become a co-dominant with ponderosa pine and incense-cedar. Plants other than trees now occupy sites formerly unfavorable for them—flowering dogwood (*Cornus nuttallii*), for example, has become established at Black Spring since 1943 (fig. 7C).

Sampling of several forested sites showed that the herbaceous understory is varied, both in species and density (appendix table 3). Although the tree cover is often essentially the same, there is a great deal of difference in understory plants on wet and dry sites (figs. 13, 14).

Causes of tree increase

THE INCREASE in woody plants was often attributed to the ceasing of burning by the Indians, but another hypothesis to explain the increase was postulated by W. H. Hall after his visit to the Valley in 1881 (Hall, 1882):

> The use of the valley itself by the constant travel and the grazing of animals upon it, is beginning to tell upon the character and extent of its vegetable productions. The finer forage grasses are being thinned out; the coarser and more robust or hardy grasses and weeds, able to withstand the trampling and cropping, are taking their places; and the area of meadow is decreasing, while young thickets of forest or shrub growth are springing up instead. . . . The cause is alleged to be the abolition of the old practice of burning off the thickets, which practice formerly made new clearings almost every year for grass growth. Doubtless this clearing had its effect in this way, but another cause, and perhaps a more potent one, is to be found in the continued cropping of the grass and trampling of the ground by horses. The finer grasses are cropped off, pulled up, trampled under foot into soft meadow ground, while coarser growths are avoided by browsing animals and permitted to flourish. The soil and the subsoil of the meadows is becoming compacted, and percolation of waters therein is arrested, so that they dry out earlier each year; the change in character of their forage vegetation results, and the thicket growths encroach upon their borders.

Hall was not the only person to note the impact of grazing on vegetation during this period. The Commissioners' Report for 1885–1886 states in part:

> During the season now closing—with its list of visitors largely in excess of former years—the utmost resources of the valley were drawn upon and exhausted for pasturage. Any increase of demand must be met by a timely increase of meadow land area, and the Commission has no choice but to appeal to the State on this behalf. The truth is that, under the strain of over-pasturage, the best meadow lands are being injured, while all of them show narrowing lines from the encroachment of brambles and thickets of young pines, willows, and cottonwoods, and some of them are so entirely overgrown as to have passed out of a pasturage classification into that of woodland.

It seems safe to assume that overgrazing was a factor in 1870 when trees began to increase in number. In 1868 there were only 623 visitors, but in 1869 visitors numbered 1,122, and this increase meant that the meadows, already grazed by residents' livestock, were grazed by many additional animals. 1870 is only the approximate beginning of widespread increase in trees; many became established in the late 1870's and early 1880's when grazing was severe.

Hall (1882) made an accurate analysis of grazing factors which contributed to the spread of trees: Heavy grazing allows seedlings to become established by reducing the competition from sedges, grasses, and broad-leaved plants. Trampling creates drier conditions by compacting the soil and, in very wet areas, by forming a rough, ridged surface which increases evaporation and drying. Exposure of mineral soil provides an excellent seedbed. With conditions favoring seedling establishment, the absence of fire allows trees and shrubs to develop. Even if occasional fires do occur their effectiveness as a killing agent is greatly lessened because herbaceous fuel is scarce.

There is no evidence that the early spread of trees in meadows was facilitated by a lowering of the water table, and it is unlikely that deposition raised land levels significantly between 1851 and 1870. Blasting of the rocks in the river channel at Bridalveil in

Figure 8A. The upper end of Yosemite Valley as it appeared between 1887 and 1896; the Stoneman House is visible on right. Young conifers are visible among the black oaks. Photograph by George Fiske; exact date unknown.

Figure 8B. Upper end of Yosemite Valley, 1943. The black oaks have been overtopped by ponderosa pine and incense-cedar. National Park Service photograph.

1879 was the first recorded event which might have caused an appreciable lowering of the water table, but this was 10 years after the start of tree invasion. Ernst (1961) has suggested the possibility of a lowering of the water table by natural processes coincident with early settlement of the Valley, but this cannot be substantiated. Evidence already presented indicates that tree invasion occurred in wet habitats; in addition, willows and cottonwoods (adapted to very wet conditions) were not abundant when white man arrived but increased after his arrival. Only the marshes appear to be too wet for establishment of a coniferous cover, and no soil habitat in the Valley is too dry.

Since trees have become established in meadow areas after grazing

Figure 8C. View of same area in figures 8A and 8B but taken from a ledge above the original point to avoid screening trees. Photograph by R. P. Gibbens, 1961.

ceased (fig. 11), it seems most probable that fire was the major factor in suppressing them before 1851. Heavy grazing, which coincided with the first widespread establishment of trees, was more an accelerating than an initiating factor. The drying influence of trees, and possible lowering of the water table, did not influence early tree increase because these factors became operative only later.

Effect of cutting, clearing, and planting on the forests

BESIDES being instrumental in increasing the extent of the forests, man has affected the character of the forest cover in many other ways. Pre-1851 forests and woodlands were thinned by early settlers

Figure 9. A dense understory of incense-cedar is often found in forested areas on the Valley floor. The trees grow very slowly and may take over 20 years to reach a height of 6 feet. Photograph by R. P. Gibbens, 1962.

Figure 10. Young ponderosa pines often occur in great abundance in small openings in the forests at the foot of talus slopes. A "young" black oak tree (probably 40 to 50 years old) is also shown. Photograph by R. P. Gibbens, 1961.

seeking cabin logs and firewood. With the creation of the Yosemite Grant it was unlawful to "cut down or carry off any wood, underwood, tree, or timber, or girdle or otherwise injure any tree or timber, . . ." without permission of the Commissioners. But this rule was not rigorously enforced, and permission was easy to obtain if logs were needed for building or firewood.

John Muir, among others, operated a sawmill in the Valley for J. M. Hutchings about 1870. Logs were obtained from a large windfall and it is doubtful if much standing timber was cut for the mill although mature trees were cut for other purposes. In the Guardian's Report for 1880, J. M. Hutchings stated: "Growing trees, of great size and beauty, have been felled, contrary to law and the order of your honorable Board." Evidently no action was taken and the cutting of trees continued. An article in the San Francisco Examiner (Hutchings, 1888) brought the "timber slaughter"

to public attention. According to the article, a 3-acre grove of cottonwoods, a number of large oaks, and assorted other "noble" trees had fallen to the axe in 1887. Further evidence of tree cutting, primarily around the Stoneman House, was contained in an article in the San Francisco Examiner for November 29, 1888. These cutting operations were concentrated in the upper part of the Valley and probably significantly reduced the number of pre-1851 trees.

After 1870 the spread of trees and shrubs was increasingly influenced by the activities of man. Cultivated areas were kept free of young trees, and loss of valuable grazing land led to more clearing efforts. During the seasons of 1891 and 1892, men were employed to thin some of the thickets of young pines and cedars and clean up combustible material; about 150 acres were partially reclaimed. More clearing was done during 1897 or 1898, and practically every annual report during the early years of the Army administration mentions the need for clearing in the Valley, although little seems to have been done until 1911 when some undergrowth was removed.

The 1914 Report of the Acting Superintendent states, in part:

> The clearing of thickets is a very important part of the work on the floor of the valley and becomes necessary to safeguard the

Figure 11. Young ponderosa pines (4 to 6 years old) in Stoneman Meadow. This is an example of the invasion of meadow areas which has been going on for many years. Photograph by R. P. Gibbens, 1961.

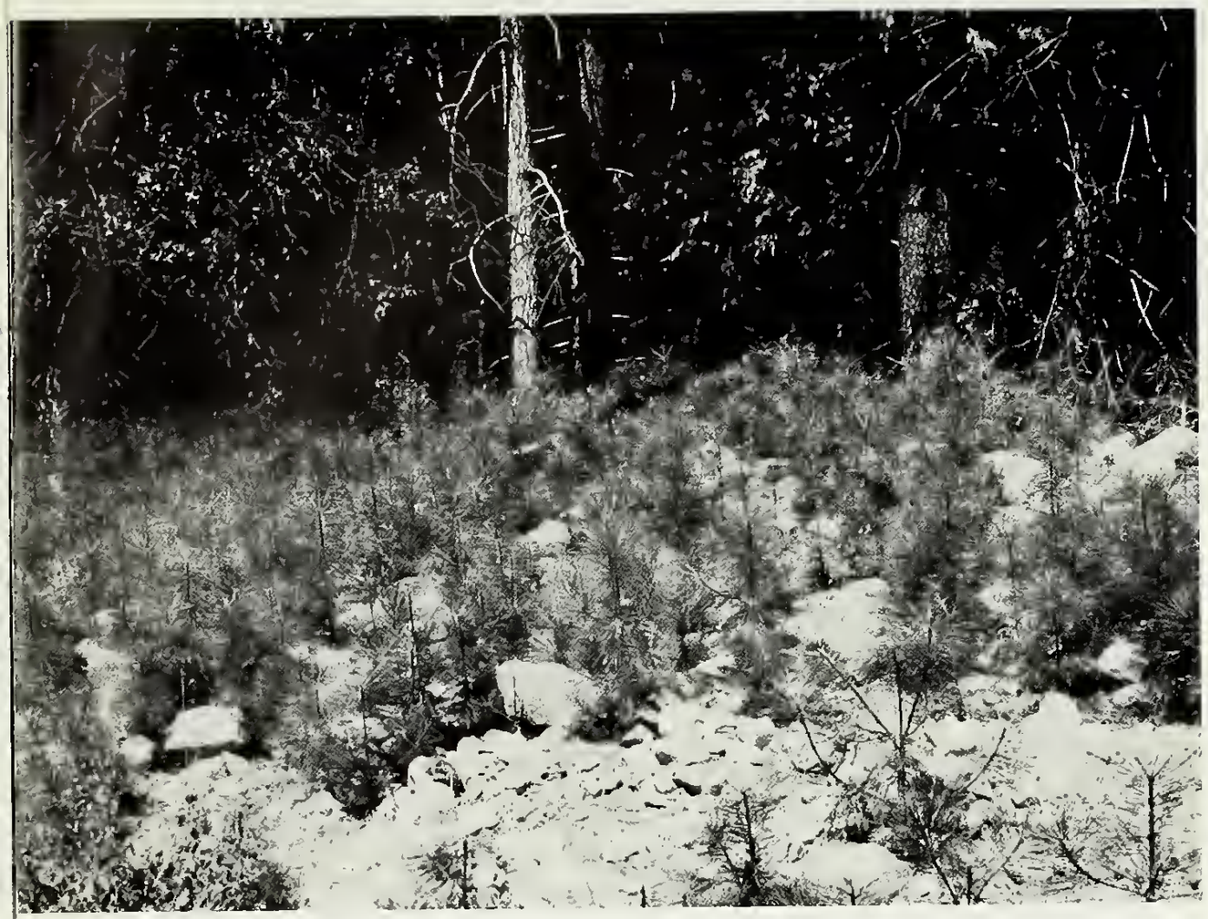


Figure 12. Young ponderosa pines at edge of a torrent channel between Cathedral Rocks and Sentinel Rock. Establishment of trees in open areas such as this has led to the dense stands now found in the Valley. Photograph by R. P. Gibbens, 1961.

Figure 13. Understory of bracken fern (*Pteridium aquilinum* var. *lanuginosum*) and western raspberry (*Rubus leucodermis*) characteristic of forests on low, wet sites on the Valley floor. Photograph by R. P. Gibbens, 1961.

growing trees both from fires and natural destruction of its own, caused by rapid and dense growth.

There were approximately 150 acres cleared this season on the floor of the valley, and the work continues in connection with wood-cutting, . . .

The objective of the clearing and thinning operations was set for the National Park Service in 1919, and the report of the landscape engineer (Punchard, 1919) appointed to study landscaping problems says:

Generally it was concluded that the present growth was greatly in need of attention and that thinning on the floor of the valley should be undertaken for two reasons—first, to preserve the health of the larger trees and as a protection against serious fires, and, second, that thinning and clearing of the meadows would tend to open up and develop very interesting open spaces and vistas on the valley floor. It is not the intention to do this work in a drastic manner and reclaim the floor of the valley entirely and thus reproduce the conditions which existed at the time of the Indians, but to confine the work to such lines as will make the woodlands safer from the standpoint of fires and also produce a pleasing landscape effect.

Figure 14. Forested area at base of talus slopes, where tree canopy is open and ground cover is usually sparse. Pine bluegrass (*Poa scabrella*) and lupine (*Lupinus greyii*) are the principal herbaceous plants. Photograph by R. P. Gibbens, 1961.

The vista-clearing concept was not new to the Valley—in the 1800's J. M. Hutchings had cut a lane through the trees so his guests would have a clear view of Yosemite Falls.

During the 1920's, wood and pole cutting was used to open vistas and thin trees in campground areas; cutting of insect-infested trees (which had begun in 1915) was also continued and some idea of the extent of tree-removal for all purposes is indicated by the 1,000 stumps blasted out along the roads in 1930. Oyster-shell scale also took a heavy toll of cottonwoods and willows during the 1920's. Thinning of trees and cleanup of dead brush and timber reached a peak during the Civilian Conservation Corps (CCC) days, and most of the Valley floor was affected. Such activities have been continued to a lesser degree to the present day. In addition to vista-clearing, snags and unsound trees are pruned or removed for public protection. Generally, such activities have had little effect on the extent of the forests, but constant thinning has influenced the relative abundance of species, particularly in campgrounds.

From about 1914 to 1924 some meadows were intentionally burned, killing many small trees and brush plants. In 1930, 9,170 small trees were cut from El Capitan meadow. In 1943, trees were again removed from El Capitan and other meadows (figs. 15A, 15B), but clearing did not end the problem of tree invasion in those meadows, as indicated by a 1961 photograph (fig. 15C).

Despite natural abundance, trees have also been planted at various times. Sequoia (*Sequoia gigantea*) and sugar pine were unsuccessfully planted along several roads in 1913, but in the CCC days, local species (primarily incense-cedar) were transplanted in order to screen barrow pits, campgrounds and comfort stations, and many of these trees still survive.

Figure 15A. Woodland in El Capitan Meadow, 1943. Young ponderosa pines are abundant. National Park Service photograph.

Changes in the meadows

MEADOWLAND in the Valley is divided into several more or less distinct areas which have had names loosely applied to them (fig. 16). Grazing, long a major meadow use, began when the Mariposa Battalion camped on Bridalveil Meadow in March, 1851, and increased with the appearance of settlers and tourists. Fences were erected around meadows at an early date (figs. 1A, 6A), and by 1888 there were 700 acres of land, presumably mostly meadowland, under fence. Various transportation operators used El Capitan Meadow for pasture in the 1870's and 1880's. Until 1892, Slaughter House Meadow was reserved for the pasturage of fat stock brought in for slaughter; army troops quartered in the Valley grazed their horses and pack stock on Sentinel and other meadows.

Grazing declined as automobiles increased, but dairy herds continued to use the meadows (fig. 17). The Slaughter House and Lamon Meadows were still fenced in 1919 and were used for pasturing pack stock. Widespread grazing ended in 1924 when most fences were removed, and all grazing was discontinued in 1933 when the tule elk penned in Cook's Meadow were removed. Only a very small part of Lamon Meadow remains in the present stable complex.

Meadows were also widely used for growing hay. An Army Engineers Map, made from data collected in 1878–79, shows a hay

Figure 15B. El Capitan meadow after young trees were removed by Civilian Conservation Corps personnel. National Park Service photograph taken in 1944.

Figure 15C. View of El Capitan meadow in 1961. Young ponderosa pines are once again present in large numbers. Photograph by R. P. Gibbens.

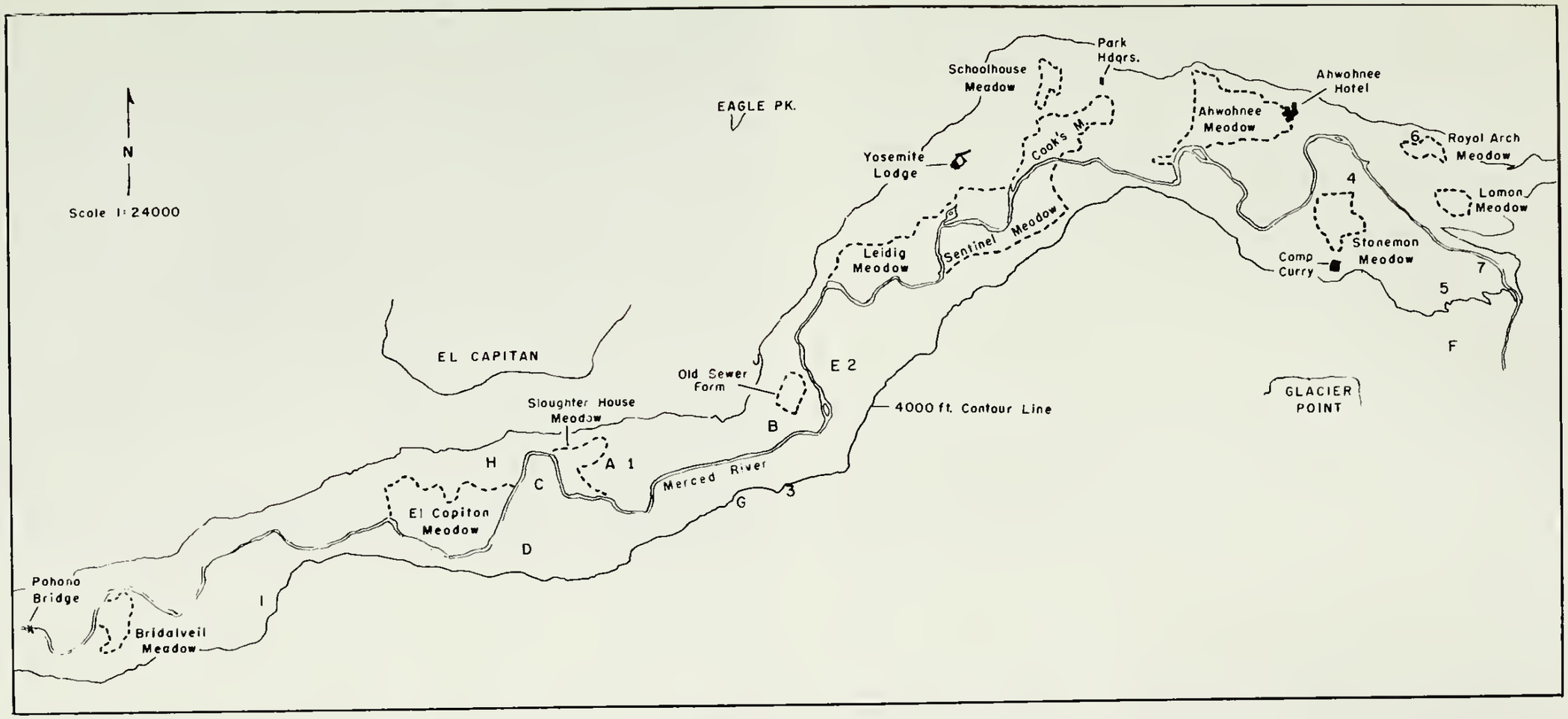


Figure 16. Map of Yosemite Valley showing the location of meadows and sampling sites.

shed in El Capitan Meadow; at least 20 acres of El Capitan Meadow was plowed and sown to timothy in the 1870's in an unsuccessful hay growing project, and Leidig Meadow was plowed in 1885 and 1887 to raise hay, and again in 1888 when wheat was sown. Part of the Ahwahnee Meadow was plowed during the late 1800's, and from 1910 to 1914 it was plowed and sown to hay by government employees. According to testimony at the Investigation of the Yosemite Valley Commissioners (California Legislature, 1889), Stoneman Meadow was cleared and plowed in 1887; the investigation placed the acreage under cultivation at that time at about 150 acres. Galen Clark testified at the hearing that cultivation was considered a means of "reclaiming" meadowlands.

Portions of the Lamon, Stoneman, and Schoolhouse meadows were planted to orchards which still exist. The Schoolhouse Meadow was the site of gardening activities by J. M. Hutchings, and by Valley residents during the two World Wars; hay barns and the Yosemite Park and Curry Co. warehouses were formerly located on this meadow. In 1941, small plots in El Capitan meadow were cultivated and sown to native plants in an unsuccessful attempt to re-establish wildflowers. Some of the meadows were drained for

mosquito control. Ditching of unspecified meadow areas was done in 1932, and drainage tiles still exist in Royal Arch Meadow.

The old Sewer Farm is a man-made meadow (fig. 2B, 2C). In 1866 the area was covered by brush and probably developed a tree cover during the 70's and 80's. In 1921 it was cleared to provide space for settling basins of the first centralized sewage system, but with the completion of the present sewer plant in 1931 operations ceased and the dikes and tanks were leveled in 1932. Today the vegetation is essentially meadow-like in character, although some trees have become established.

Ahwahnee, Cook's and Bridalveil meadows were burned intentionally in 1919, 1920, 1921, and 1930. The Ahwahnee meadow was accidentally burned in 1929, and other meadows probably have been burned by accident.

The problem created by tourists' use of the meadows (fig. 18) is mentioned in the Superintendent's Monthly Report for June, 1929:

> Ditches constructed around the meadows on the floor of the Valley have aided materially in protecting these spaces from encroachment by tourists. With autos traversing them constantly, and with daily picnics being held in these meadows, the native flowers and grasses were rapidly becoming a thing of the past.

Figure 17. Dairy herd in Leidig Meadow, 1918. Until 1924, several meadows were grazed by dairy herds during summer months. National Park Service photograph

Figure 18. Stoneman Meadow as it appeared in May, 1927. Use of meadows for picnics and camping was common in the early 1900's. Construction of ditches along roadways in 1929 brought a halt to such use. National Park Service photograph.

Construction of these ditches ended the last general use of meadow areas; deer and other wildlife use the meadows today. Foot traffic is not extensive except in Stoneman Meadow and along the river banks. The remaining meadow areas are largely the product of man's activities. Plowing, mowing, burning, and probably in some cases severe overgrazing, served to keep out encroaching trees; in addition, clearing activities of the 1890's, 1930's and 1940's have prevented the establishment of woody growth. Boundaries of the present meadows could probably be correlated with the location of fences which delimited activities.

A major change in the meadows has been their decrease in size due to forest encroachment. Whitney (1868) classified 745 acres as meadowland. Russell (1927) using 1922 U. S. Geological Survey maps of Yosemite Valley placed the meadow acreage at 430 acres.

Ernst (1949) measured the meadow area on an unpublished vegetation-type map prepared in 1937 and found 327 acres of meadow; planimeter readings from aerial photographs taken in 1960 show approximately 334 acres of meadow. Recent invasions by trees (figs. 11, 15C) indicate that only continued tree removal will maintain the meadows as open areas.

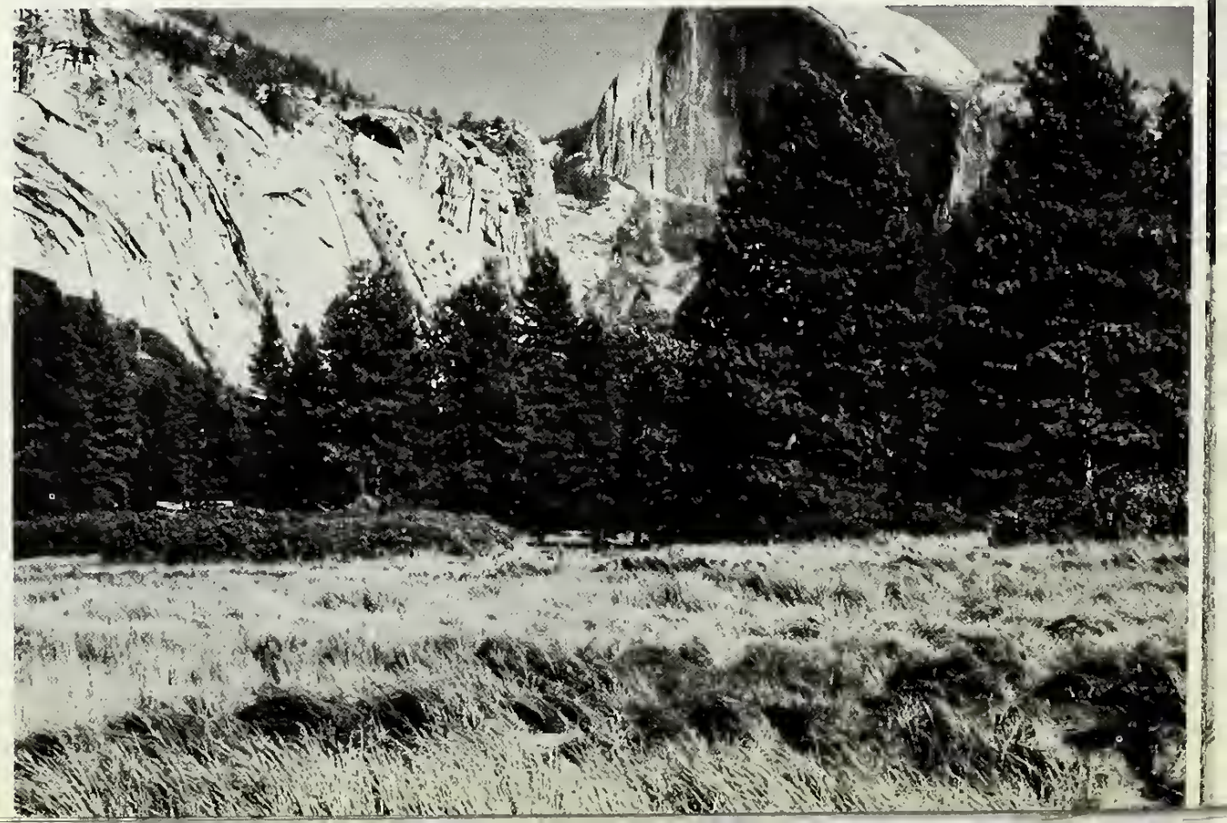
Today, the meadow vegetation only partially fits Whitney's (1868) description: "consists chiefly of carices or sedges and a few coarse grasses . . ." For the present study, all of the major meadow areas (except the Schoolhouse Meadow) were sampled to determine the kinds of plants present (appendix table 4). Sedges (*Carex* spp.) are still very abundant and it seems safe to assume the species (not given by Whitney) are essentially the same today, although their relative abundance may be different. The "coarse grasses" listed as characteristic of the meadows by Whitney are all adapted to very wet habitats. The present rarity of these grasses indicates that the meadows are much drier now.

Next to sedges, Kentucky bluegrass (*Poa pratensis*) is the most abundant plant in the meadows. Undoubtedly, Kentucky bluegrass was introduced, as was redtop (*Agrostis alba*), another grass prominent in the meadows today. Annual grasses, also introductions, are abundant in sandy or disturbed sites. Only one native grass, wildrye (*Elymus* spp.), is probably much more abundant today. While sedges typically predominate in the lower, wetter portions of the meadows, the abundance of plants (such as Kentucky bluegrass) adapted to relatively dry sites further substantiates the deduction that the meadows are, in general, drier than when seen by Whitney.

Aside from the shift to plants adapted to a drier habitat, there is little remaining evidence of the plowing and heavy grazing of the past. On meadows which were plowed sedges have re-established themselves wherever moisture conditions permit. The Elk Paddock has completely recovered from the relatively recent heavy grazing (see both photographs in figure 19). If the Elk Paddock and the adjacent Superintendents part of Cook's Meadow, which was not grazed during the same period, are compared (appendix table 4), it is evident that differences in kind and abundance of species are minor. In Lamon Meadow, another area of recent heavy grazing, sedges are least abundant. This may be due to the compacting and

Figure 19A. Elk Paddock portion of Cook's Meadow between 1921 and 1933; note heavily grazed condition inside the fence. National Park Service photograph.

Figure 19B. Elk Paddock site, 1961. Photograph by R. P. Gibbens.



drying action of trampling, but there are few low areas which are favorable for sedges. Soil factors may also play a part in species distribution.

Broad-leaved plants are not abundant on the meadows. There are many references through the years to the decreasing numbers of wildflowers in the meadows. Michael (1929) stated: "June of the year 1920 witnessed the last great bloom on the floor of the Valley."; she attributed the comparatively small numbers of flowers present in 1927 to the influence of mowing, burning, deer, and people, although these factors were also operative prior to 1920. The same author also noted that after being absent or nearly so from 1923 to 1935, various lilies appeared in great abundance, even on meadows which had been plowed (Michael, 1935). Obviously, it is difficult to determine if wildflowers are now more, or less, abundant than in 1851.

Abundant production of fruiting stalks by a wide variety of plants common to the lower Sierra Nevada is assumed to be climatically controlled. The optimum combination of moisture and temperature needed for such production in many species occurs only in widely-spaced years, and this helps account for the fact that myriads of flowers may be seen one year and only a few in another year. To blame the decline on grazing or some other factor is especially hazardous; valid comparisons should be based on the actual number of plants and not on the number of flower stalks.

Plowing, mowing, and grazing has undoubtedly reduced the population of certain wildflowers, while populations of some rare but attractive species have been decimated by picking and trampling. Perhaps the re-establishment of sod-forming sedges and grasses and the accumulation of a heavy mulch layer prevented the return of wildflowers after disturbance had ceased: It is also possible that lack of disturbance could decrease the wildflower populations; grazing, for example, would reduce mulch and weaken the sod-formers. Certainly, any species favored by burning is less likely to be found today than in 1851. The great variety of wildflower species means that there will be some which will increase with disturbance and some which will decrease, some which will increase with protection and some which will decrease.

Introduction of plants

NUMEROUS plant species were brought to California by the Spaniards as early as the 16th century and many others have arrived since. Some of these scattered rapidly and by the middle of the 19th century were widespread and abundant in California (Burcham, 1957). Although the Spaniards rarely penetrated into the Sierra Nevada, the wanderings of Indians and natural dissemination by wind and animals could have introduced non-indigenous plants to the Valley before 1851.

With the entry of early visitors a great importation of plants began, and conditions favorable for the establishment of introduced species were created. Plowing and heavy grazing broke up or weakened the cover of native plants, creating space readily occupied by the well-adapted introductions, many of which were brought in with the hay, grain, and seed imported for feed and cultivation. Seeds were widely disseminated over the Valley floor by grazing animals and by man, and disturbed areas were often deliberately seeded with plants foreign to the Valley. Out of 470 known species of plants on the Valley floor and lower portions of the talus slopes, 18 per cent are non-indigenous (appendix table 5).

Introduced trees and shrubs are not a significant part of the vegetation outside the orchards planted by the early settlers, although apple trees have naturalized to some extent. Introduced grasses which have become naturalized are very abundant. Kentucky blue-

grass is a major meadow plant, redtop was undoubtedly introduced as a hay plant and has spread throughout the Valley, other hay grasses are found scattered in the meadows, and velvet grass (*Holcus lanatus*) has become widely established in wet habitats. Most of the annual grasses are introduced species, and are now major constituents of the herbaceous vegetation throughout the Valley.

Generally, introduced broad-leaved plants are weeds found in small numbers on disturbed areas. Some of these, such as thistle (*Cirsium vulgare*) and Klamath weed (*Hypericum perforatum*), successfully compete with established vegetation and have been the object of control measures because they detract from the natural appearance of the meadows. Control of all weedy species in the Valley is not necessary; some may become temporarily abundant due to favorable climatic conditions, but they are unlikely to displace the more desirable perennials. Since weeds flourish on disturbed areas, the best control is to keep disturbance at a minimum. Because of their long-lived seeds, many weeds will remain a potential, if not active, part of the vegetation.

Re-establishment of plants on denuded areas

MAN'S activities, and natural events such as floods and rockslides, have caused much denudation—although little evidence of such events remains because of rapid re-establishment of plants. The

Figure 20A. Gravel road skirting the north side of Elk Paddock in the late 1920's or early 1930's. Photographer and date unknown.

Figure 20B. North side of Elk Paddock site, 1943. (Paddock fence was removed in 1933.) National Park Service photograph.

Figure 20C. North side of Elk Paddock site, 1961. Old road was torn up in 1953. Photograph by R. P. Gibbens.

present distribution of species on such disturbed areas reflects moisture gradients and soil differences, and not the type of disturbance. The old Sewer Farm, for example, is now completely revegetated; where remnants of the old dikes impede drainage there is a dense cover of sedges, surrounded by wild-rye. Part of this area lies on the Eagle Creek outwash fan where rapid drainage and occasional deposition of material creates conditions ideal for abundant annual grasses. A few trees and shrubs have become established and, barring further disturbance, others are likely to appear.

In the spring of 1959 the Old Village store was removed, and in 1961 its site was sampled to determine the extent of recovery and the kinds of plants found on recently disturbed areas. Red fescue (*Festuca rubra*) had been sown on the site and was the most abundant plant, but annual weeds—characteristically the first invaders of denuded areas—were abundant (appendix table 6). Sedges and perennial grasses from the bordering meadow had gained a strong foothold on the site by 1961. Young trees were not present at this time, but may appear while herbaceous cover is sparse.

Development of rhizomes by the dominant meadow plants enables them to move into disturbed areas very quickly, and perennials, when firmly established, crowd out annual species (see fig. 20C). Such disturbed areas may be identified for a long time, not because of species differences, but because of differences in plant size or color. On sandy or other dry sites introduced annual grasses, which are better adapted to less moisture than are perennials, may become the dominant plants.

Well-adapted native and introduced herbaceous species are the best choices for artificial revegetation of denuded areas. "Foreign" species, such as red fescue, may be successful temporarily but will usually be replaced by the natives. Trees may become established on denuded sites along with herbaceous plants, and may develop concurrently; when this happens the trees become dominant. Woody plants are often the primary invaders on rock slides; shrubs and young ponderosa pine trees were well established 9 years after a large rock slide at Rocky Point, but few herbaceous plants were present (Carlson, 1932).

Wildlife Influences

DEER and rodents are the animals most likely to significantly affect vegetation in Yosemite Valley. Although wildlife was protected in the Valley after 1864, deer did not increase greatly until they were protected throughout Yosemite National Park, and by effective game laws outside the Park. The Acting Superintendent's Report of 1912 contains the first mention of an increased deer population; since then the population has fluctuated, with excess resident animals being removed when necessary.

Herbaceous plants constitute a major part of deer's diet, as browse plants are not abundant in the Valley. Some deer-relished plants, such as evening primrose (*Oenothera hookeri*), have apparently been reduced in abundance by the animals. Young white fir trees and favored shrubs are often hedged by browsing, thus greatly slowing their growth, and the limited reproduction of black oak (particularly in the grove surrounding Yosemite Village) has been attributed to deer browsing. A survey of the relatively deer-proof Ahwahnee Hotel grounds reveal a few small black oaks less than 1-foot tall, with one tree found outside the fence. As the grounds have been fenced since 1929, more young oaks and a number of different age groups would be expected if deer were the only limiting factor involved.

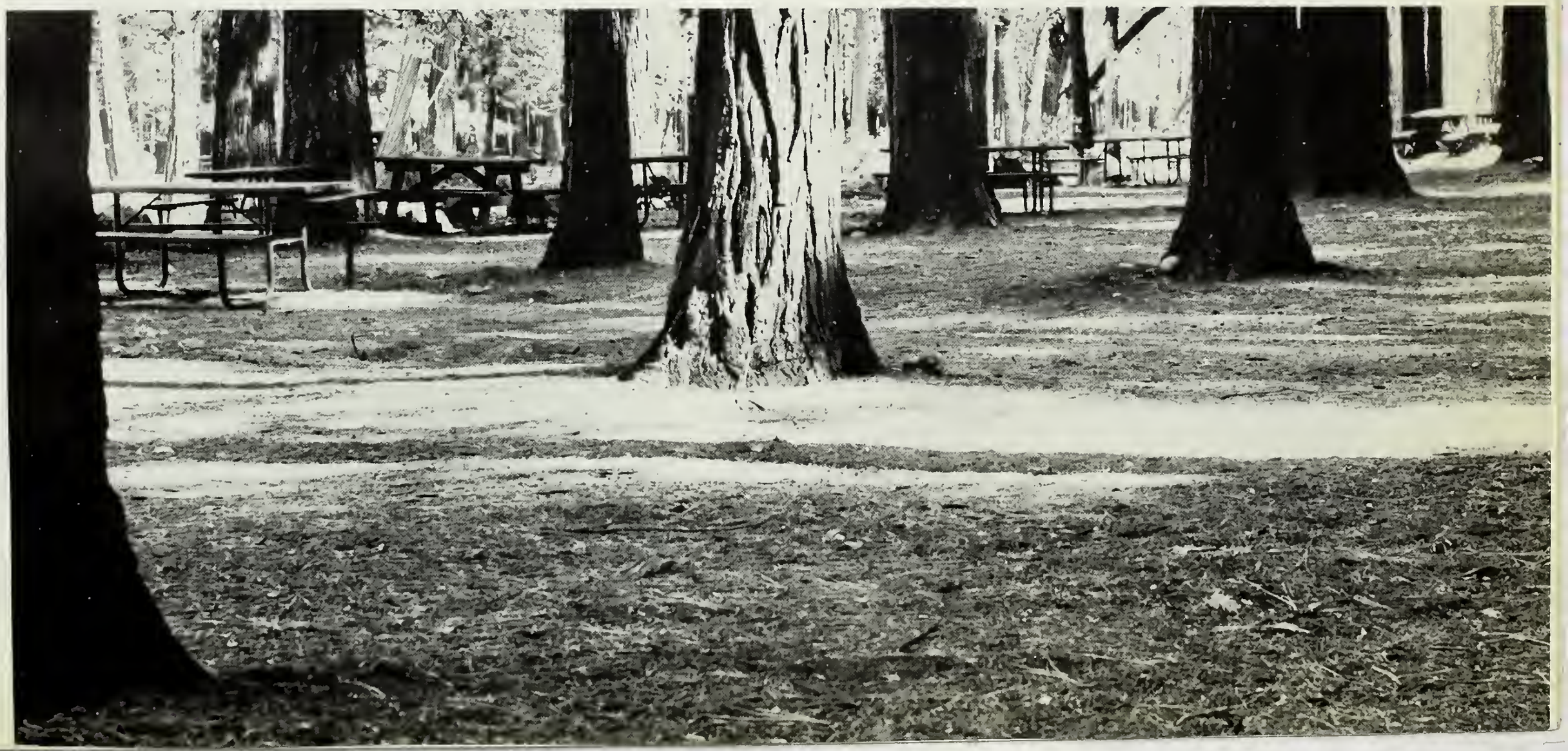
Black oak seedlings have appeared in large numbers at least once in relatively recent times. Payne (1938), commenting on the ex-

ceptionally large crop of acorns produced in 1936, states: "With the lapse of a year since the sprouting of the acorns, we find a great host of these seedling oaks growing most vigorously." Reasons for the present scarcity of black oak reproduction are not known. Consumption of acorns may be a factor, but deer are not the only acorn users present. Any one of a number of factors—disease, insects, viability of acorns, competition from other plants, and climatic factors—may also be involved. Black oak grows very slowly and if perpetuation of the grove is desired efforts should soon be made to determine which factors are limiting reproduction.

Three exclosures were erected in 1935 to determine the effect of deer browsing and grazing, but little was learned save that deer seem to have had a minimum of influence on the vegetation. However, the exclosures are small and no record of vegetation on open control plots was compiled.

Rodents may possibly have played a part in the early spread of trees in the Valley. The bare soil of gopher-workings in meadows would make excellent seedbeds, and seeds buried in animals' caches would be a source of seedlings; however, during population peaks rodents could reduce tree-establishment by eating seeds and girdling young trees. Too little is known about the rodent populations to evaluate their effect on the vegetation, but such effects have been restricted by the rodent trapping and poisoning programs carried out since 1912.

Figure 21. Camp 14. Note absence of small trees, herbaceous cover, and heavy litter normally found under similar stands of trees. Photograph by R. P. Gibbens, 1961.



Influence of floods and rockslides

FLOODS, rockslides, and avalanches have a catastrophic effect on vegetation. Major floods occurred in 1867, 1890, 1919, 1937, 1950 and 1955. Hutchings (1886) described the flood of 1867 as follows:

> On December 23, 1867, after a snow fall of about three feet, a heavy down-pour of rain set in, and incessantly continued for ten successive days; when every little hollow had its own particular water-fall, or cascade, throughout the entire circumference of the Valley; each rivulet became a foaming torrent, and every stream a thundering cataract. The whole meadow land of the Valley was covered by a surging and impetuous flood to an average depth of nine feet. Bridges were swept away, and everything floatable was carried off.
>
> Immense quantities of talus were washed down upon the Valley during this storm,—more than at any time for scores, if not hundreds, of years, judging from the low talus ridges, and the timber growth upon them. After this rain-storm had ceased, a wind sprung up and blew down over one hundred trees. In one spot of less than seven acres twenty-three large pines and cedars were piled, crosswise, upon each other.

Such floods inundate areas normally not flooded by spring runoff. The flood of 1950 covered 55 per cent of the nearly level floor of the Valley, and one in 1955 covered even more area. Floodwaters do not stand long enough to cause wholesale drowning of plants, but by erosion or deposition and changing of the river channel they can influence the abundance and growth of plants; for example, bare areas so created may be occupied by vegetation different from that previously existing in the same area.

Since 1879 there has been a continuing and not entirely successful struggle to confine the Merced River to its channel and to halt the cutting of banks, as both meadow areas and trees have been undermined and swept away by the river. Efforts to contain the river may have caused a deepening of the channel, and with such deepening, overflow is lessened, drainage is quicker, and the water table is lowered. These facts indicate that the low-lying ground may now be drier in summer than it was before 1851.

Rockslides shear off or bury plants in their path, and several have occurred since 1851. The fall of Eagle Rock in the earthquake of 1872, which John Muir (1912) described so vividly, snapped off huge fir trees and covered a large area with a rubble pile many feet thick; much of this area is still bare of vegetation. Slides of lesser proportions (such as the one at Rocky Point in 1923) are not so long-lasting in their effect. Wildfires can also have a catastrophic effect on vegetation, although most fires on the Valley floor have been quickly controlled.

Figure 22. Denuded and trampled river bank at west end of Camp 14. The pile of rocks is one of many efforts made to halt cutting of stream banks by the river. Photograph by R. P. Gibbens, 1961.

Influence of visitors

THE present boundaries of campgrounds in Yosemite Valley were established in the 1930's and these areas have born the full impact of increasing use. During the summer of 1958 there were 8,800 to 12,000 campers in the Valley's campgrounds each night (National Park Service, 1958). Campgrounds in the Valley are all in forested areas, yet, with so many people moving about, the ground is devoid of herbaceous plants and young trees (fig. 21). Ernst (1947) lists only two plants, miner's lettuce (*Montia perfoliata*) and false Solomon's seal (*Smilacina amplexicaulis*), which appeared year after year in campground areas. Miner's lettuce produces seed before the peak of camping activity, and false Solomon's seal produces stems from underground rootstalks. Even adapted plants such as these can survive for only a short period each year.

Vehicular and foot traffic compacts soil, and this influences vegetation. Soil compaction in campgrounds was found to be significantly higher than in immediately adjacent areas (appendix table 7). Compaction dropped off sharply at campground boundaries, even though adjacent areas are subject to foot traffic. Compacted soils have less air space, lowered water infiltration rate, and increased runoff—conditions which are unfavorable to plant growth.

The litter and duff layers characteristic of forest floors are reduced by campers. Pine needles, the principal constituents of litter and duff layers in the Valley's forests, make excellent kindling for fires and as a result are removed each year. In Camp 14 the litter collected in September from 25 random square foot quadrats was equivalent to 2.5 tons of oven-dry material per acre. Under a similar stand of trees where camping was not an influence, litter and duff from 25 square foot quadrats was equivalent to 17.4 tons per acre. Of this amount 9.8 tons were duff, or largely decomposed organic matter, a layer that was non-existent in the campground. Larger debris has been removed for fuel from campgrounds and from the upper end of the Valley in general.

Constant removal of litter results in a loss of nutrients normally returned to the soil by the breakdown of organic matter. While leaching of campfire ashes and addition of material through spilled foodstuffs may partially offset this loss in nutrients, organic matter—important in maintaining soil structure—and nitrogen are not replaced.

Because the Merced River bisects the campground area and is a focal point of activity, its banks are trampled bare (fig. 22). Before campgrounds were established the river banks supported a thick cover of shrubs and herbaceous plants; today, herbaceous plants are gone and the remaining azalea clumps have been broken by people (see all photographs in figure 23). River banks at favored bathing beaches and picnic areas also show the effects of trampling, but outside the areas of high human concentration trampling is largely confined to paths along the river.

An indication of what would happen in the present campgrounds if people were excluded was furnished by the temporary closing of campgrounds 7 and 15 during 1943, 1944, and 1945 (Ernst, 1947). Tree seedlings appeared and herbaceous plants recovered rapidly, especially near protected spots and guard rails at camp boundaries where the seed source was located. Several campgrounds, abandoned for sanitary reasons soon after 1906 and still not in use as campgrounds, now show no evidence of past trampling.

Buildings and roads continue to influence the vegetation. Buildings serve as focal points of human activity, and trampling often creates disturbed areas around them. Extensive walks and paved areas have reduced trampling, but the runoff from such non-absorptive surfaces influences vegetation on adjacent areas.

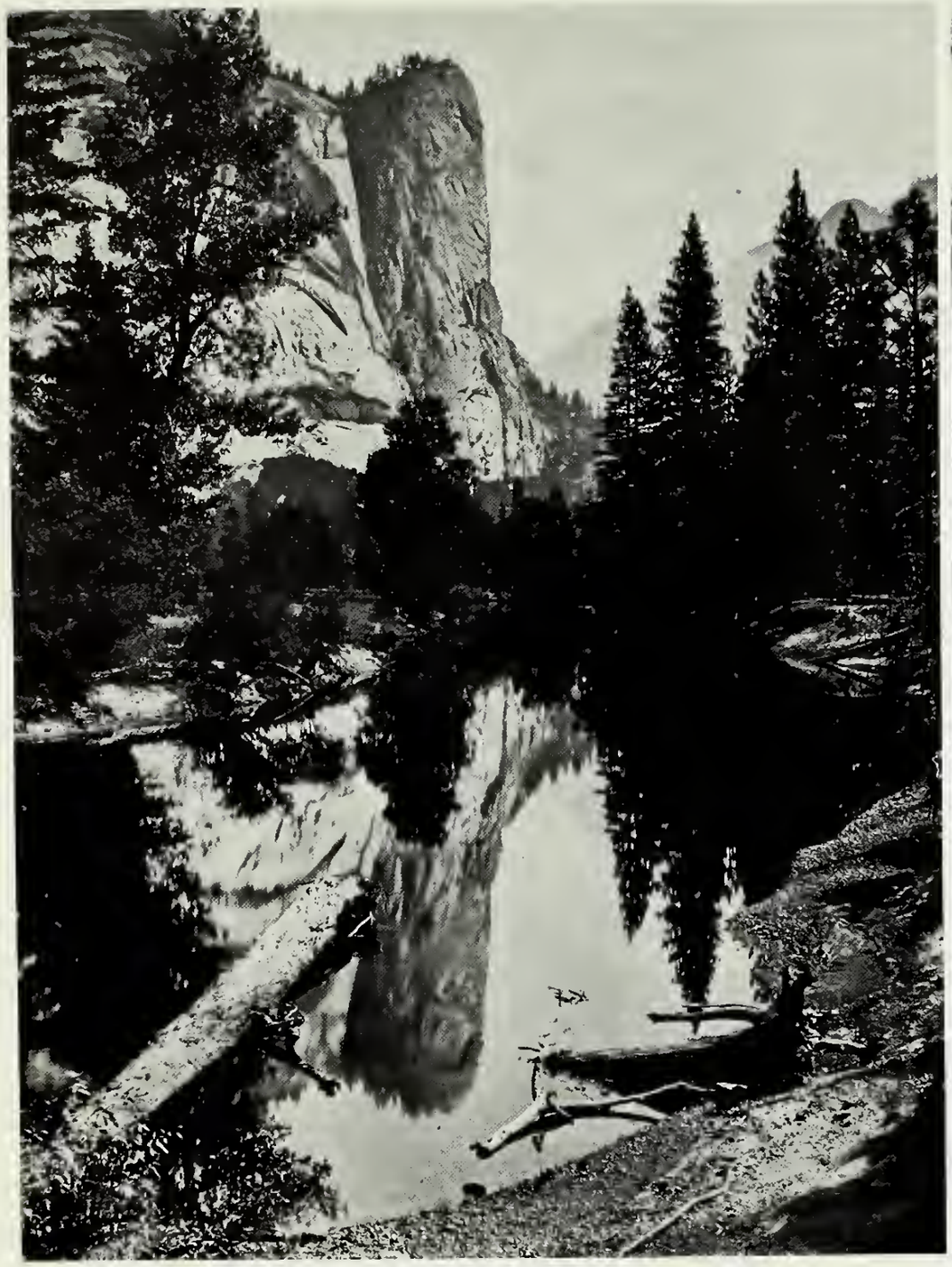


Figure 23A. Early photograph taken from below the present site of Stoneman Bridge. (Washington Column in background.) Photographer and date unknown.

Figure 23B. The river below Stoneman Bridge, 1943. River bank on the left borders Camp 7; shrubs and herbaceous plants have been trampled out by campers. National Park Service photograph.

With the exception of Lamon Meadow, all the Valley's meadows are skirted or bisected by major roads. The fill and ditches of roads have had considerable influence on drainage patterns and have doubtless changed soil-moisture conditions. A small swamp supporting a stand of cattails (*Thypa latifolia*) has been formed in the Black Spring drainage by the damming action of the highway. The influence of roads is seldom this marked, the shift usually being from a wet to a dry meadow. The dry, frequently disturbed road shoulders and embankments are often a haven for weedy annuals.

Opening of the forest canopy for power lines, installation of pipelines, collection of gravel from the river bed and diversion of springs for water supplies have also caused changes in plant cover.

Figure 23C. The river below Stoneman Bridge, 1961. Photograph by R. P. Gibbens.

Discussion

To preserve or enhance the beauty of the vegetative landscape of Yosemite Valley it is essential that there be management of the vegetation. This view was held by Frederick Law Olmsted, co-designer of New York's Central Park and head of the first Yosemite Commission, and was well stated by W. H. Hall in 1882:

> If in the judgment of men who have studied such things, for their love of the beautiful and the appropriate, who have striven from professional motives and for professional distinction, in the improvement of the great parks of the principal eastern cities, large trees can be cut away with advantage, where it has cost so much of time, money, and skill to raise them, certainly you should be safe from censure if, in opening out the views, caring for the full development of the timber, and clearing up the more unsightly parts of the valley lands of the Yosemite, you apply the axe right freely.

Today, ecological knowledge enables us to predict vegetation changes under various kinds of management and we also have the technical ability to produce almost any desired landscape. But, unhappily, the aesthetic criteria for making decisions as to what vegetative landscape is desired appear to be lacking—and for Yosemite Valley the decisions must be made soon.

On aesthetic grounds, a primitive state of tree density is frequently deemed more desirable than the present one. Trees are now so numerous in the Valley that any selected density and extent of forest

can be obtained by selective cutting, although it would probably be impractical to thin the forests to their primitive low-density. However, some thinning must be done for other than aesthetic reasons: a dense understory of young trees often forms a solid block of fuel from the ground to the tallest tree tops, and this is a potentially catastrophic situation if fire occurs.

Although perhaps undesirable in some areas, dense stands of trees are useful in screening the Valley's extensive campgrounds from view. In the campgrounds a preponderance of sandy soils has minimized the effect of trampling, but the soils have been altered and the present tree cover may be adversely affected. Since there is a lack of young trees in these areas, a time limit—the life span of the existing trees—has been placed on the screening forest. Therefore, steps to protect tree health and to provide replacements for dead or dying trees should be taken. One solution might be to rotate campground use; during periods of closure an understory of herbaceous species could be established by sowing, and replacement trees could be planted.

To maintain the meadows in the Valley as open areas will require continued removal of trees. Selective tree removal is expensive but effective. Other methods, such as prescribed burning, might be less costly or more long-lasting, but their effect on herbaceous vegetation would have to be evaluated before they are used on a large scale.

The presence of the many introduced herbaceous plants in the meadows must be accepted because they cannot be completely and permanently eradicated. And indeed, many of these introductions are desirable. On Stoneman Meadow, for example, Kentucky bluegrass maintains a pleasing appearance despite trampling which would cause more robust native sedges to become unsightly. Again, introduced annual grasses provide cover on many areas too dry to support a good cover of perennials. Only those introductions which detract from scenic values need to be controlled. It is unlikely that the sedges, which add much to the attractiveness of the meadows, will be replaced by other plants as long as present moisture conditions prevail. Creation of wetter conditions by changing drainage patterns might be an effective method of increasing the numbers of sedges and other moisture-loving plants.

There is, of course, an alternative to management of the vegetation, and that is the acceptance of the landscape which will develop naturally. This alternative has been consistently rejected in the past, and, if aesthetic criteria are used, continued rejection is likely in the future.

Acknowledgments

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Appendix

METHODS OF STUDY

The quarter method (Cottam and Curtis, 1956) was used to sample trees in seven forest stands on the Valley floor. A line of march was selected, 100 feet paced off, and a plot center established by means of a rod placed at the toe of the boot. With the line of march as one axis and a line at right angles to it as another axis, four 90-degree angles, or quarters, were established. The tree over 2 inches d.b.h. (diameter breast high) nearest to the pin was measured and recorded by tree species for each quarter. In each stand, 25 points were sampled, giving 100 measured individuals. From these data the relative abundance as based on number of individuals (appendix table 1) and on basal area (appendix table 2) was calculated.

The relative abundance of herbaceous plants and trees on ten forest sites was calculated from data collected by a modified step-point method of sampling (appendix table 3). Three steps were taken along a compass line and a pin placed at the toe of the front boot. The closest rooted plant in front of the pin was recorded. The rooted plant closest to the step-point was sometimes a tree, recorded as mature, young (under 4 inches d.b.h.), or seedling (1 and 2 years old for conifers, under 1 foot for oaks). The seedling designation for oaks was used merely to distinguish recent reproduction. This is not an ideal method to use in a forest because two different

APPENDIX TABLE 1

RELATIVE ABUNDANCE OF TREES WITH A D.B.H. OF 2 INCHES OR MORE EXPRESSED AS PERCENTAGE OF TOTAL NUMBER OF TREES CONTRIBUTED BY EACH SPECIES*

Species	Site Number						
	1	2	3	4	5	6	7
	per cent						
Pinus ponderosa	40	45	54	56	26	59	12
Libocedrus decurrens	53	39	29	37	56	28	20
Quercus kelloggii	4	11	14	2	16	8	7
Abies concolor	3	4	1	5	1	5	54
Quercus chrysolepis	0	1	2	0	0	0	2
Pseudotsuga menziesii	0	0	0	0	1	0	4
Cornus nuttallii	0	0	0	0	0	0	1

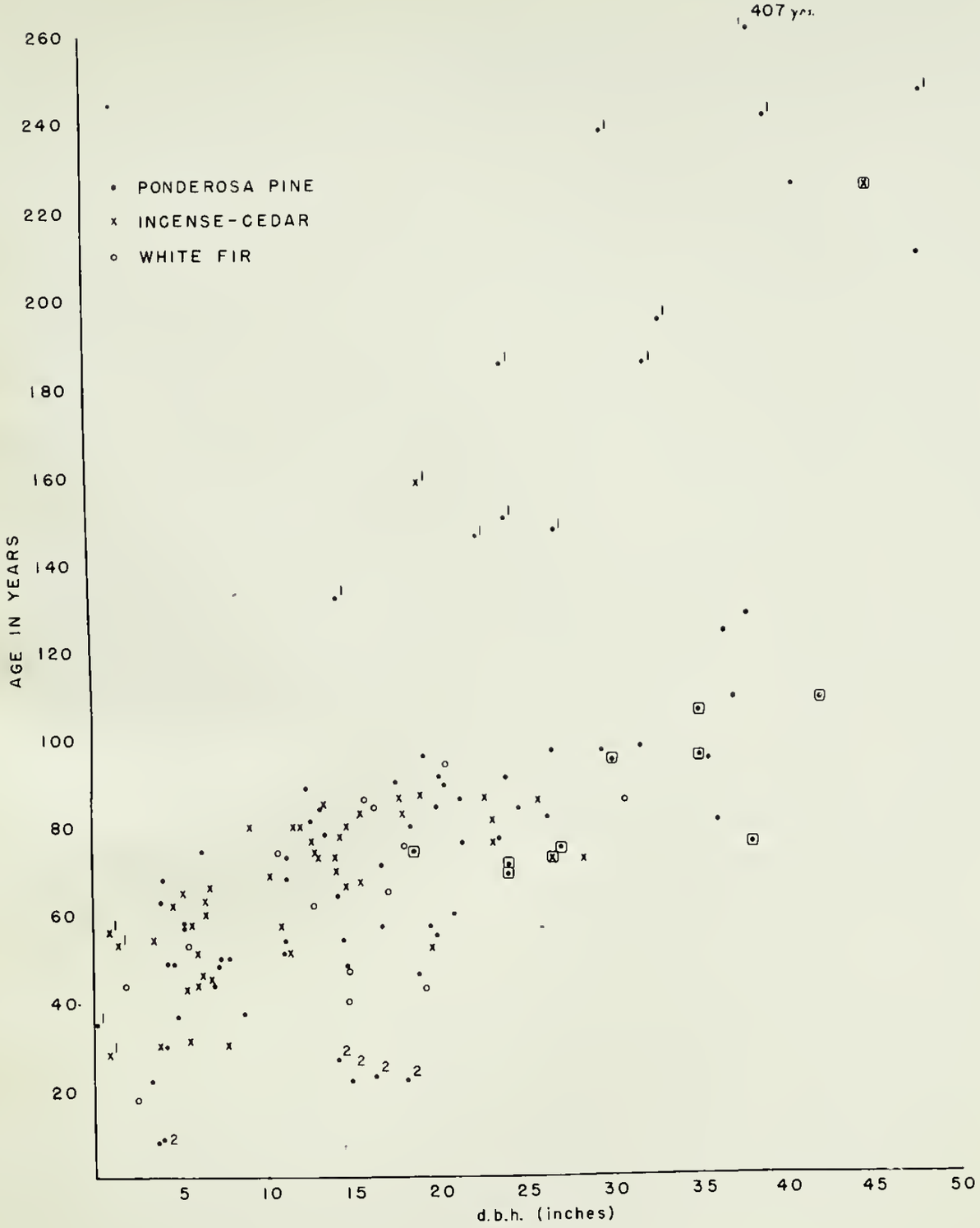
* Calculated from 25 quarter-method samples taken on each of seven forest sites located on the Valley floor (see figure 16 for site locations).

APPENDIX TABLE 2

RELATIVE BASAL AREA OF TREES WITH A D.B.H. OF 2 INCHES OR MORE EXPRESSED AS PERCENTAGE OF TOTAL BASAL AREA CONTRIBUTED BY EACH SPECIES*

Species	Site Number						
	1	2	3	4	5	6	7
	per cent						
Pinus ponderosa	64.2	68.0	54.2	62.3	54.4	86.5	33.3
Liboeedrus deeurrens	29.1	20.0	29.3	29.9	35.4	10.7	17.7
Quereus kelloggii	6.5	9.4	16.3	3.1	8.9	1.6	9.4
Abies concolor	0.2	2.5	0.1	4.7	0.9	1.2	31.4
Quereus ehrysolepis	0.0	0.1	0.1	0.0	0.0	0.0	1.1
Pseudotsuga menziesii	0.0	0.0	0.0	0.0	0.4	0.0	7.0
Cornus nuttallii	0.0	0.0	0.0	0.0	0.0	0.0	0.1

* Calculated from 25 quarter-method samples taken on seven forest sites on the Valley floor (see figure 16 for site locations).



life forms—trees and herbaceous plants—are intermixed, but it was a rapid method and furnished a measure of the relative abundance of the different species. The number of trees recorded indicates their relative proportion in the total vegetation.

The relative abundance of species on the meadows was calculated from rooted frequency as determined by the modified step-point method described above (appendix table 4). Due to scarcity of fruiting bodies and lack of distinctive vegetative differences the species of sedges could not always be distinguished. However, the principal species in approximate order of abundance were *Carex barbarae, C. vesicaria, C. feta,* and *C. kelloggii.* Wild-rye was not separated into species due to the intergradation of forms. In general *Elymus triticoides* is found in open areas and *E. glauca* in wooded areas. Species listed as "other perennial grasses" in appendix table 4 include *Stipa californica, S. columbiana, Muhlenbergia filiformis, M. rigens, Panicum occidentale,* and *Calamagrostis canadensis;* "other annual grasses" include *Bromus commutatus, Festuca reflexa, F. dertonensis,* and *Deschampsia danthonoides.* Only the most common forbs are listed in appendix table 4. Nomenclature is based on Munz and Keck (1959).

APPENDIX FIGURE 1.

Total age of trees as estimated from growth ring counts in 1961. The range of d.b.h. classes (diameter breast high—about 4.5 feet) was sampled at several sites on the Valley floor. Symbols enclosed in a square represent stumps whose diameter is larger than the d.b.h. Since most of the samples were taken from trees on former meadow areas the invasion of trees appears to have started approximately 90 years ago. Diameter of the trees is closely correlated with age but this correlation is influenced by site. For example, trees marked "1" are from dry sites at the base of talus slopes and are much older than trees of comparable diameters from level portions of the Valley floor. Trees on very favorable sites (marked "2") have a large d.b.h. in relation to their age. Understory trees, many of which are less than 10 inches d.b.h., are quite old.

APPENDIX TABLE 3

RELATIVE ABUNDANCE OF SPECIES ON TEN FOREST SITES ON THE VALLEY FLOOR EXPRESSED AS PERCENTAGE OF TOTAL NUMBER OF PLANTS CONTRIBUTED BY EACH SPECIES*

Species	Site									
	A	B	C	D	E	F	G	H	I	J
	per cent									
Carex spp.	4.0	0.0	10.0	1.3	4.0	3.3	13.3	0.0	0.0	0.0
Elymus spp.	14.0	11.3	48.0	1.3	2.0	15.3	5.3	4.7	6.0	4.0
Bromus marginatus	0.0	0.0	0.0	2.0	0.0	1.3	0.0	1.3	0.0	0.7
Stipa elmeri	0.0	4.7	0.0	1.3	0.0	3.3	0.7	0.0	0.0	0.0
S. californica	0.0	0.0	0.0	4.6	0.0	4.0	4.7	9.3	0.0	0.7
Poa scabrella	0.0	0.0	0.0	0.0	0.0	2.6	8.6	0.7	22.0	14.6
Sitanion hystrix	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.7	0.0	0.0
Bromus tectorum	0.0	1.3	0.0	0.0	0.0	24.0	8.0	0.0	7.3	7.3
Other grasses	4.7	2.1	0.0	0.7	0.7	0.7	0.7	2.7	1.4	2.0
Pteridium aquilinum var. *lanuginosum*	26.6	18.0	10.6	9.3	26.0	0.0	0.0	7.3	0.7	0.7
Galium spp.	0.0	10.6	3.4	1.3	0.7	2.0	5.3	2.0	4.6	2.7
Osmorhiza brachypodia	10.0	8.7	3.3	0.0	14.6	0.0	0.0	0.0	0.0	0.0
Kelloggia galioides	2.6	2.0	1.3	22.0	0.7	0.0	0.0	0.0	0.0	0.0
Rumex acetosella	3.3	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Asarum hartwegii	0.0	0.7	0.0	0.7	0.0	0.0	0.0	0.0	0.7	0.0
Artemesia douglasiana	0.7	0.7	5.3	0.0	0.0	0.7	0.0	0.0	0.0	0.0
Draperia systyla	0.0	0.0	0.7	0.0	1.3	0.7	0.0	0.0	0.0	0.7
Gayophytum nuttallii	0.0	0.0	0.0	0.7	0.0	1.3	1.3	0.0	0.0	1.3
Strepthanthus tortuosus	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	12.0
Erigeron breweri	0.0	0.0	0.0	0.0	0.0	0.7	1.3	0.0	0.0	0.0
Lupinus greyii	0.0	0.0	0.0	0.0	0.0	0.0	21.3	6.0	0.0	0.0
Lessingia leptoclada	0.0	0.0	0.0	0.0	0.0	2.0	6.7	0.0	0.0	0.0
Brickellia californica	0.7	0.0	0.0	0.0	0.0	0.7	0.0	0.0	7.3	6.6
Penstemon laetus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	5.3
Eriophyllum confertiflorum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Other forbs	2.1	2.0	4.0	4.8	2.1	6.1	10.7	4.8	5.3	0.0
Rubus leucodermis	0.0	12.6	3.3	0.7	4.0	0.0	0.0	0.0	0.0	0.0
Rhamnus rubra	0.7	0.0	0.7	0.7	0.0	0.0	0.0	9.3	0.0	0.7
Lonicera interrupta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.7	0.7
Ribes roezlii	0.0	0.0	0.0	0.0	0.7	0.0	0.7	0.0	0.7	0.7
Philadelphus lewisii	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0
Arctostaphylos mariposa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	0.0	1.3
Other shrubs	0.7	1.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.7

APPENDIX TABLE 3—*Continued*

Species	Site									
	A	B	C	D	E	F	G	H	I	J
	per cent									
Libocedrus decurrens										
Mature	1.3	2.7	0.7	1.3	4.6	6.7	0.0	0.0	2.0	0.7
Young	4.6	4.0	0.7	21.3	25.2	7.3	1.3	0.0	10.6	2.6
Seedling	6.0	4.7	0.7	3.3	9.3	2.6	0.0	2.0	0.0	0.0
Pinus ponderosa										
Mature	2.6	3.3	0.0	0.0	2.0	0.0	2.6	4.0	0.0	12.0
Young	0.7	0.0	1.3	6.0	0.7	1.3	0.7	12.0	0.0	1.3
Seedling	0.7	1.3	3.3	0.7	0.7	0.0	0.0	4.0	0.0	10.0
Quercus kelloggii										
Mature	0.7	0.0	0.0	0.0	0.0	0.7	0.0	2.0	1.3	2.0
Young	10.0	0.0	0.0	3.3	0.0	0.0	0.7	6.7	0.0	0.7
Seedling	0.0	3.3	0.0	0.7	0.7	0.7	0.0	1.3	0.0	1.3
Abies concolor										
Young	1.3	0.0	0.7	9.3	0.0	2.0	0.7	0.0	1.3	0.7
Seedling	0.0	0.0	0.0	0.7	0.0	4.7	0.0	0.0	0.7	0.0
Quercus chrysolepis										
Mature	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.3	0.0
Young	2.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	6.0	4.0
Seedling	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.7	0.0
Pseudotsuga menziesii	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.7	0.0
Umbellularia californica	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	10.6	0.0
Acer macrophyllum	0.0	0.0	1.3	0.0	0.0	5.3	0.0	0.0	0.7	0.0
Alnus rhombifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0

* Calculated from rooted frequency as determined by 150 step-point samples on each site (see figure 16 for site locations).

APPENDIX TABLE 4

RELATIVE ABUNDANCE OF SPECIES ON THE MAJOR MEADOW AREAS IN YOSEMITE VALLEY EXPRESSED AS PERCENTAGE OF TOTAL NUMBER OF PLANTS CONTRIBUTED BY EACH SPECIES*

Species	Meadow												
	Bridalveil	El Capitan		Slaughter House	Leidig	Sentinel	Cook's		Ahwahnee	Stoneman	Lamon	Royal Arch	Old Sewer Farm
		Open	Wood-land				Superinten-dents part	Elk Paddock					
	per cent												
Carex spp.†	80.1	36.0	17.6	21.0	29.4	47.6	74.2	67.8	51.9	13.0	0.7	78.1	26.6
Poa pratensis	4.0	40.3	35.9	21.3	51.0	22.0	11.0	21.7	27.7	68.3	68.0	10.2	1.7
Elymus spp.†	5.3	7.3	10.7	25.3	15.0	26.7	8.0	0.0	0.0	0.0	0.0	0.0	38.4
Agrostis alba	0.0	2.0	7.0	3.3	0.0	0.0	0.7	4.0	1.3	8.0	2.0	0.5	0.0
Other perennial grasses†	0.0	4.3	7.0	1.3	1.0	0.0	0.0	0.3	0.3	2.0	0.7	0.0	0.0
Bromus tectorum	0.0	1.0	0.0	7.0	0.3	0.0	0.0	0.0	15.0	5.4	19.3	0.0	19.4
Other annual grasses†	0.0	0.0	0.0	12.1	1.7	1.0	0.0	0.3	0.0	0.0	5.3	2.7	1.7
Total grasses and sedges	89.4	90.9	78.2	91.3	98.4	97.3	93.9	94.1	96.2	96.7	96.0	91.5	87.8
Juncus effusus	1.0	4.0	5.0	0.7	1.0	0.0	0.0	0.3	0.0	0.7	0.0	0.5	0.3
J. orthophyllus	1.7	1.3	0.0	0.7	0.3	1.7	0.7	0.3	1.0	1.0	0.7	0.0	0.0
Equisetum laevigatum	0.0	0.7	2.3	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.7	0.0	0.0
Scirpus acutus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2	0.0
Iris missouriensis	0.0	1.8	2.3	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Helcocharis spp.	0.0	0.0	0.0	0.0	0.0	0.0	3.3	1.3	0.0	0.0	0.0	0.0	0.0
Solidago spp.	1.6	0.0	3.0	1.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.5	0.0
Fragaria californica	0.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Asclepias cordifolia	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.3	0.7	0.0	0.0	0.0	0.0
Artemisia douglasiana	0.0	0.7	1.7	0.7	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0
A. dracunculus	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rudbeckia hirta	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	2.7
Hypericum formosum	1.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Lotus oblongifolius	5.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rumex acetosella	0.0	0.0	0.0	2.4	0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Achillea lanulosa	0.0	0.0	1.0	0.0	0.0	0.0	0.7	0.0	0.3	0.0	0.0	0.0	0.0
Gayophytum nuttallii	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3
Lessingia leptoclada	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	2.0	0.0	5.3
Other forbs	0.0	0.3	4.0	0.9	0.0	1.0	1.4	3.4	0.3	0.0	0.6	1.3	3.6

* Calculated from rooted frequency as determined by 300 step-point samples in all meadows except Lamon (150) and Royal Arch (225) (see figure 16 for location of meadows).
† See appendix I for names of species.

Appendix Table 5

INTRODUCED PLANTS FOUND IN YOSEMITE VALLEY*

Trees and Shrubs

Acer saccharophorum
Cercis occidentalis
Hedera helix
Malus sylvestris
Parthenocissus quinquefolia
Prunus cerasus
Pyrus communis
Robinia pseudocacia
Rubus recurvans
Sequoia gigantea
Syringa vulgaris
Ulmus americana
Vitis spp.

Forbs

Anthemis cotula
Brassica kaber var. *pinnatifida*
B. campestris
Capsella bursa-pastoris
Cardaria draba
Cerastrium viscosum
C. vulgatum
Chenopodium album
C. botrys
Chrysanthemum leucanthemum
Cirsium vulgare
Cuicus benedictus
Convolvulus arvensis
Conyza canadensis
Digitalis purpurea
Erigeron strigosus
Erodium botrys
E. cicutarium
Galium aparine
Glecoma hederacea
Humulus lupulus
Hypericum perforatum
Ilex aquifolium
Lactuca serriola
Malva parviflora
Mentha spicata
Mullugo verticillata
Pimpinella anisum
Plantago lanceolata
Plantago major
Polygonum aviculare
P. convolvulus
P. lapathifolium
P. persicaria
Portulaca oleracea
Prunella vulgaris
Raphanus sativus
Rudbeckia hirta var. *pulcherrima*
Rumex acetosella
R. crispus
Sisymbrium altissimum
S. officinale
Taraxacum vulgare
Thlaspi arvense
Trifolium repens
Verbascum thapsus
Veronica serpyllifolia

Grasses

Agrostis alba
A. alba var. *palustris*
Avena fatua
Bromus commutatus
B. inermis
B. mollis
B. rigidus
B. rubens
B. secalinus
B. tectorum
Dactylis glomerata
Digitaria ischaemum
D. sanguinalis
Eragrostis megastachya
E. pilosa
Festuca dertonensis
F. elatior
Holcus lanatus
Hordeum stebbinsi
Lolium perenne
Phleum pratense
Poa pratensis
Setaria lutescens
S. viridis

* List compiled from Durant (1927), McDonald (no date), Woodham (1927), Michael (1929, 1935), Carlson (1932), Goen (1932), Lillard (1948), Bryant (1951), and sheets in the Yosemite Museum Herbarium. It is possible that many species have been brought in since the above collections and studies were made.

Appendix Table 6

RELATIVE ABUNDANCE OF SPECIES ON THE SITE OF THE OLD VILLAGE STORE EXPRESSED AS PERCENTAGE OF TOTAL NUMBER OF PLANTS CONTRIBUTED BY EACH SPECIES. (DATA GATHERED 2 YEARS AFTER REMOVAL OF THE STORE.)*

Species	Per cent
Festuca rubra	31.3
Elymus spp.	22.7
Poa pratensis	10.7
Agrostis alba	1.3
Sitanion hystrix	0.7
Carex spp.	1.3
Bromus rigidus	1.3
B. tectorum	0.7
Sisymbrium altissimum	22.7
Lactuca serriola	1.3
Capsella bursa-pastoris	0.7
Chenopodium botrys	0.7
C. album	1.3
Rumex acetosella	1.3
Artemesia douglasiana	0.7
Unidentified	1.3

* Calculated from rooted frequency as determined by 150 step-point samples.

Appendix Table 7

DEGREE OF SOIL COMPACTION INSIDE AND OUTSIDE CAMPGROUNDS AS MEASURED BY A SOIL PENETROMETER*

Location	Soil	Area	Use	Number of samples	Mean compaction value*
Camp 14 east end	sandy-loam	inside	heavy	39	2.82
		outside	moderate	10	1.16
Camp 14 central part	sandy-loam	inside	heavy	40	2.34
		outside	moderate	38	1.40
Camp 14 west end	sandy	inside	heavy	50	1.35
		outside	moderate	50	0.48
Camp 11 west end	sandy-loam	inside	heavy	50	2.78
		outside	moderate	50	1.24
East of Yellow Pine Beach	sandy	forest	very light	50	0.55
North of El Capitan Beach	sandy to sandy-loam	forest	very light	50	0.60

* The larger the value of the means the greater the degree of compaction. Differences between the means of samples from inside and outside the campgrounds were highly significant.

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